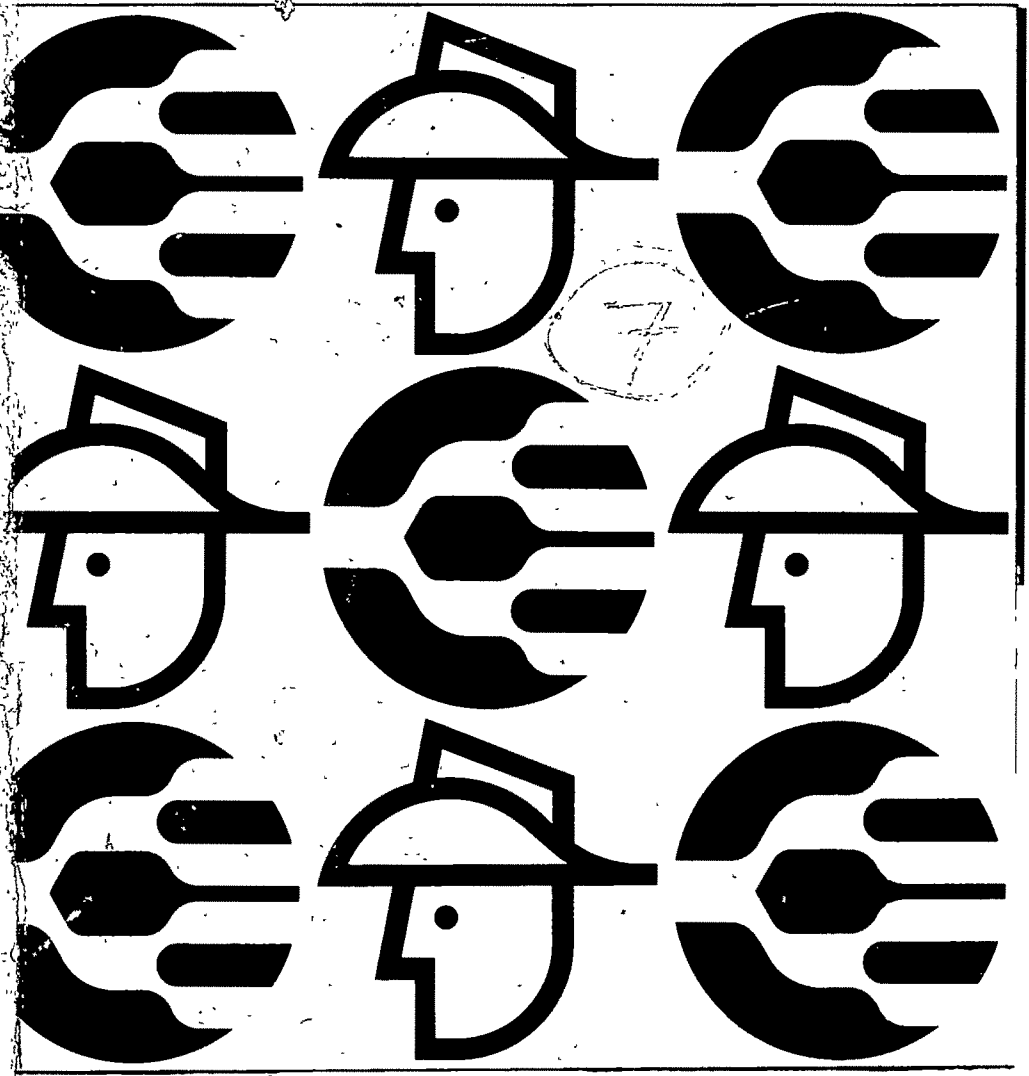
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39th NATIONAL MEETING

Dallas, Texas

May 5–7, 1971

REGISTRATION INFORMATION

Registration

The Registration Desk will be located on the second floor level of the Sheraton-Dallas Hotel and will accommodate preregistered and unregistered delegates at the following times:

Tuesday, May 4	6 00 p.m. – 10:00 p.m.
Wednesday, May 5	8:00 a.m. – 5:00 p.m.
Thursday, May 6	8:00 a.m. – 5:00 p.m.
Friday, May 7	8:00 a.m. – 2:00 p.m.

Fees for registration and functions are as follows:

ORSA Member Registration	$30.00
Non-member Registration*	35.00
Full-time Student Registration	5.00
International Buffet Luncheon (Friday)	5.00

It is the policy of the Operations Research Society of America that all attendees at this meeting, including all speakers and chairmen, pay the registration fee for the meeting. In addition, payment must be made for any of the special events attended.

Preregistration

Preregistration with or without pre-payment for the meeting is strongly encouraged. A preregistration form is enclosed. Please make check or money order payable to 39th ORSA. Send to: G. Alan Laureyns, 3908 Clayton Road West. Fort Worth, Texas 76116. In returning the preregistration form, please indicate the special events you wish to attend.

Accommodations

The Sheraton-Dallas Hotel, 2117 Live Oak St., Dallas, Texas 75221 is the official headquarters and meeting hotel. A block of rooms has been reserved for attendees. Daily rates are indicated on the enclosed hotel reservation form. To reserve a room, mail the enclosed form directly to the Sheraton-Dallas Hotel.

THE PROGRAM

The program for this meeting encompasses a broad range of operations research topics. Particular depth is found in the technical areas of mathematical programming and

*A non-member submitting an application for membership when registering may register at the member rate. a membership desk will be located in the registration area.

stochastic decision-making, in applications to problems of today's society, and in the basic philosophy of operations research.

"Distinguished Lectures" will be given on Wednesday, May 5, and Thursday, May 6, at 1:00 p.m. in the Sam Houston Room. As the "Distinguished Lectures" promise to be of general interest, they are conveniently scheduled before the afternoon sessions begin.

In Distinguished Lecture I, Professor Harvey M. Wagner will speak on "The ABC's of O.R." A well-known educator and corporate consultant, Professor Wagner has authored many publications, including the book, *Principles of Operations Research*, awarded the 1969 Lanchester Prize for the year's outstanding publication in operations research.

In Distinguished Lecture II, Professor Thomas L. Saaty will speak on "The Present Status and Future Growth and Needs of Operations Research in the Government". Professor Saaty has written ten books and is a noted authority on governmental and military applications of operations research.

The majority of the sessions have themes of specific interest to operations researchers. Some of these will be conducted as panel discussions led by representative experts encouraging audience participation. The others will consist of invited and contributed talks related to the session themes with time generally allowed for questions after presentations. Particularly noteworthy is the "Student Papers Section" to which students have contributed papers. Awards will be given to the two best papers as judged by a panel of leading operations research professionals.

The remaining sessions contain contributed papers to be presented simultaneously. During the hour and fifteen minutes of a session a speaker may schedule repeated presentations or discuss his work at length with those individuals most interested in the topic. These sessions specifically contain a variety of topics so as to minimize potential conflicts for the attendee, who is invited to visit as many presentations as may interest him. For those wanting to carry on discussions outside of these sessions a room with blackboards will be available.

Abbreviations are used to identify the sessions and papers in them. The first letter, W, T, or F, denotes the day of the week; and the second, A or P, indicates morning or afternoon, respectively. The first numeral distinguishes the session, while the second gives the position of the paper in the session. Invited papers are indicated by an asterisk.

SPECIAL FUNCTIONS

The initial event on the special functions calendar is the $\overline{\text{OR}}$ (the OR bar) from 6:00 to 8:00 P.M. on Wednesday, May 5. Held in the Grand Ballroom of the Sheraton, this mixer promises to be anything but traditional. You are welcomed to a Western saloon setting by the Golden Cowboy assisted by a bevy of "dance hall girls." A Texas-size bar (40 feet in length) and reminders of distinguished citizens from Lone Star history (Billy the Kid, Wild Bill Hickock, etc.) contribute to the scene. Entertainment is provided by a Mariachi (Mexican strolling) band. Hors d'oeuvres are plentiful; do not miss the nachos and chili conqueso. Refreshment is also Texas style—all you can drink.

On Thursday, May 6, ORSA members are "stagecoached west" to the Austin Patio Dude Ranch. Very casual dress is suggested. The reception at the Ranch is provided by the Tarrant County Sheriff's Posse. A real, "sho-nuff" Texas barbecue with all the trimmings is the fare. With the setting of the sun (about 7:15 P.M.), the rodeo begins. Calf roping, bulldogging, and steer riding are all on tap plus much more. Closing the night's entertainment is the "hoedown"—western music and square dancing at its best.

Concluding the special functions for the week is the International Buffet Banquet in the Grand Ballroom of the Sheraton from 12:00 to 2:00 P.M. on Friday, May 7. The buffet features prominent dishes from Mexican, Italian, and Polynesian cuisine as well as

American delicacies. Complementing the buffet menu is a large choice of wines. President W. Edward Cushen is to deliver the retiring presidential address at the Banquet

A post-convention tour to Mexico City and Acapulco has been arranged for the week following the meeting. Departing Dallas at 6:00 P.M. on Friday, May 7, tour participants will jet non-stop to Mexico City. Visits to Guadalupe and Taxco are included, and tours of Chapultepec Park and Castle, the Flower Market, and the National Palace are scheduled. The memorable Folkloric Ballet and the bullfights top the entertainment list. A yacht cruise on Acapulco Bay and a trip to the impressive cliffs of La Querbrada conclude the stay in Acapulco. Return flights on Sunday, May 16, are to be arranged individually. The trip price is $355 per person (assuming double occupancy, add $77 for single), and for further information or arrangements contact:

Travel Consultants, Inc.
1025 Connecticut Avenue, N.W
Washington, D.C. 20035
Area Code (202) 659-9555

LADIES' PROGRAM

There will be a women's registration booth in the lobby of the Sheraton-Dallas on Wednesday, May 5, 8:00 a.m.–5:00 The State Room will be the women's information center and hospitality room. Late arrivals may register in the State Room on Thursday.

Wednesday, May 5

8:00– 9:30	Coffee–State Room
9:30–11·30	Shopping at Neiman-Marcus
11:30– 1 00	Champagne Luncheon Neiman-Marcus Zodiac Room
1:00– 4:00	Tour of Dallas, Theatres & Gardens

Thursday, May 6

9·00–10·00	Coffee–State Room
10:00–11:00	Goodwill Fashion Show (a show of fashions from the past to the present)–London Room
11:00– 1:00	Brunch at Brennan's
1:00– 3:30	Tour of World of Animals (drive-through game preserve)

Friday, May 7

8:00– 9.00	Coffee–State Room
9:00–10:00	Fashion Demonstration (one-woman show teaching you how to coordinate what you have)–London Room
10:00–11.30	Shopping and tour of the Quadrangle (a shopping center designed after a Mexican village)
11:30– 1:00	Lunch–Quadrangle, Yum-Yum Tree

COPIES OF PAPERS

Requests for copies of papers should be sent directly to the authors and not to the Committee for the meeting, the sessions chairmen, or the Editor of the Bulletin.

ORSA INFORMATION SYSTEM

There will be keyboard access at the meeting to an SMU-Alpha Systems time-shared program to query a file of registrant data and information about papers being presented.

THE COVER

The cover and announcement posters were designed by James Ledbetter, Ledbetter Advertising Art, Dallas, Texas.

WEATHER AND DRESS

The weather will be mild; warm-weather clothing is appropriate. The average temperature for early May is 80 degrees during the day and 60 degrees at night.

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Ladies' Program Chairwoman:	PEGGY GUE *7017 Briarmeadow Drive* *Dallas, Texas 75230*



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JABBUR, R.J., FP8.6
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KOOPMAN, B.O., TA5.2
KORTANEK, K.O., TA6.3, TP1
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WOOLSEY, R.E., FA3.4
WOODRUFF, A.P., WP8.6
WOOLSEY, G., FA3.4
WRAY, D.J., WP7.4
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WYSKIDA, R.M., WA7.6, TP8.20

YAHYA, Q.A.M.M., WA8.10
YEN, J.Y., TA3.2, TP4.5
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YOUNG, J.P., TA7.8
YOUNG, R.D., WA3.3

ZAMANI, K., WP8.15
ZOBEL, S.P., FP7.2
ZWART, P.B., WP7.12

SESSIONS CHAIRMEN

WA1	U. Narayan Bhat, Computer Science/Operations Research Center, Southern Methodist University, Dallas, Texas 75222.
WA2	Erwin Baumgarten, Center for Naval Analyses, 1401 Wilson Boulevard, Arlington, Virginia 22209.
WA3	Fred Glover, School of Business, University of Colorado, Boulder, Colorado 80302.
WA4	Harold Wool, Office of Research, U.S. Department of Labor, Washington, D.C.
WA5	Richard C. Larson, Room 9-226 CAES, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139.
WA6	Michael M. Connors, IBM Scientific Center, 1930 Century Park West, Los Angeles, California 90067.
WA7, 8	Donald M. Topkis, Department of Industrial Engineering and Operations Research, University of California, Berkeley, California 94720.
WP1	Julius Aronofsky, Graduate School of Business, Southern Methodist University, Dallas, Texas 75222.
WP2	Leonard Kleinrock, Department of Engineering, University of California, Los Angeles, California 90024.
WP3	Robert Kupperman, Office of Emergency Planning, Washington, D.C.
WP4	Eric V. Denardo, Department of Administrative Sciences, Yale University, New Haven, Connecticut 06520.
WP5	Daniel Roos, Department of Civil Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139.
WP6	Robert M. Thrall, Department of Mathematical Sciences, Rice University, Houston, Texas 77001.
WP7, 8	Gordon P. Wright, Krannert School of Industrial Administration and Department of Statistics, Purdue University, Lafayette, Indiana, 47907.
TA1	George Haering, Office of Chief of Naval Operations, (OP-96), Pentagon, Room BD 770, Washington, D.C.
TA2	John R. Hall, National Center for Health Services Research and Development, Room 15-22, Parklawn Building, 5600 Fishers Lane, Rockville, Maryland 20852.
TA3	Leon S. Lasdon, Operations Research Department, Case Western Reserve University, Cleveland, Ohio 44106.
TA4	Donald L. Iglehart, Department of Operations Research, Stanford University, Stanford, California 94305.
TA5	Robert W. Simpson, Department of Aeronautics and Astronautics, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139.
TA6	A. Charnes, School of Business Administration, University of Texas at Austin, Austin, Texas 78712. W. W. Cooper, School of Urban and Public Affairs, Carnegie-Mellon University, Pittsburgh, Pennsylvania 15213.
TA7, 8	V. J. Bowman, Graduate School of Industrial Administration, Carnegie-Mellon University, Pittsburgh, Pennsylvania 15213, and the University of Pittsburgh, Pittsburgh, Pennsylvania.
TP1	Richard V. Evans, College of Commerce and Business Administration, University of Illinois, Urbana, Illinois 61801.
TP2	Alfred Blumstein, Urban Systems Institute, Carnegie-Mellon University, Pittsburgh, Pennsylvania 15213.
TP3	Albert Shapero, School of Business Administration, University of Texas at Austin, Austin Texas 78712.
TP4	Jack Edmonds, Department of Combinatorics and Optimization, University of Waterloo, Waterloo, Ontario, Canada.
TP5	John E. Walsh, Statistics Department, Southern Methodist University, Dallas Texas 75222.

TP6	Stuart H. Mann, Division of Man-Environment Relations, Pennsylvania State University, University Park, Pennsylvania 16802.
TP7, 8	Hamilton Emmons, Department of Operations Research, Cornell University, Ithaca, New York 14850.
FA1	Jack Edmonds, Department of Combinatorics and Optimization, University of Waterloo, Waterloo, Ontario, Canada.
FA2	William D. Brinckloe, University Science Center, 3113-3125 Forbes Avenue, Pittsburgh, Pennsylvania 15213.
FA3	Arthur M. Geoffrion, Graduate School of Business Administration, University of California, Los Angeles, California 90024.
FA4	Donald P. Gaver, Department of Statistics Carnegie-Mellon University, Pittsburgh, Pennsylvania 15213.
FA5	Frank Proschan, Department of Statistics, Florida State University, Tallahassee, Florida 32306.
FA6	Joseph L. Balintfy, School of Business Administration, Department of General Business and Finance, University of Massachusetts, Amherst, Massachusetts 01002.
FA7, 8	Thomas Crabill, School of Business Administration, University of North Carolina, Chapel Hill, North Carolina 27514.
FP1	Travis E. Peace, General Dynamics, P.O. Box 748, Forth Worth, Texas 76101.
FP2	John R. Freeman, The MEDICUS Corporation, 1104 Expressway Tower, Dallas, Texas 75206.
FP3	Alan J. Goldman, Applied Mathematics Division, National Bureau of Standards, Washington, D.C. 20234.
FP4	Ferdinand F. Leimkuhler, School of Industrial Engineering, Purdue University, Lafayette, Indiana 47907.
FP5	A.W. Wortham, Texas A&M University, College of Engineering, College Station, Texas 77843.
FP6	Floyd J. Gould, Department of Statistics, The University of North Carolina, Chapel Hill, North Carolina 27514.
FP7, 8	Theodore B. Slattery, 2121 P Street N.W., Suite 213, Washington, D.C. 20037.

SUMMARY OF EVENTS

	Wednesday, May 5	AM	Room
WA1	Queueing	9:00–12:00	Pioneer
WA2	Military Applications	9:00–12 00	Sam Houston
WA3	Integer Programming	9:00–12:00	Stephen F. Austin
WA4	Manpower Cost Effectiveness Studies	9:00–12:00	W.B. Travis
WA5	Operations Research in the Administration of Justice	9·00–12:00	Vaquero
WA6	Production Scheduling, Planning and Forecasting	9:00–12:00	Alamo
WA7	Simultaneous Session I	9:00–10:15	Ballroom Foyer
WA8	Simultaneous Session II	10:30–11:45	Ballroom Foyer
	Distinguished Lecture I	1:00–1:50	Sam Houston

	Wednesday, May 5	PM	Room
WP1	Use of Computers in Industry: Portfolio Selection and Financial Management	2:00–5:00	Pioneer
WP2	Computer Systems Analysis	2:00–5:00	Sam Houston
WP3	Defense Non-defense Tradeoff Analysis	2:00–5:00	Stephen F. Austin
WP4	Dynamic Programming and Markov Decision Processes	2:00–5:00	W.B. Travis
WP5	Urban Transportation	2·00–5:00	Vaquero
WP6	Student Papers	2.00–5.00	Alamo
WP7	Simultaneous Session III	2·00–3·15	Ballroom Foyer
WP8	Simultaneous Session IV	3:30–4.45	Ballroom Foyer
	Annual Business Meeting	5:00–6:00	Sam Houston

	Thursday, May 6	AM	Room
TA1	Panel on: Tactical Air Power in the Eighties	9:00–12·00	Pioneer
TA2	Health Applications	9:00–12.00	Sam Houston
TA3	Large-Scale Systems	9:00–12.00	Stephen F. Austin
TA4	Inventory Theory	9:00–12:00	W.B. Travis
TA5	Air Traffic Control	9.00–12:00	Vaquero
TA6	Recent Research and Developments in Budgeting Theory and Practice	9:00–12:00	Alamo
TA7	Simultaneous Session V	9:00–10:15	Ballroom Foyer
TA8	Simultaneous Session VI	10:30–11·45	Ballroom Foyer
	Distinguished Lecture II	1:00–1:50	Sam Houston

	Thursday, May 6	PM	Room
TP1	Panel on: Relevancy of Operations Research	2:00–5:00	Pioneer
TP2	Urban Problems I	2·00–5·00	Sam Houston
TP3	Research and Development	2·00–5:00	Stephen F. Austin
TP4	Networks and Graphs I	2:00–5:00	W.B. Travis
TP5	Operations Research and Statistics	2:00–5:00	Vaquero
TP6	Operations Research in Ecology and Biology	2:00–5:00	Alamo

TP7	Simultaneous Session VII	2:00–3:15	Ballroom Foyer
TP8	Simultaneous Session VIII	3:30–4:45	Ballroom Foyer

	Friday, May 7	AM	Room
FA1	Networks and Graphs II	9:00–12:00	Pioneer
FA2	Urban Problems II	9:00–12:00	Sam Houston
FA3	Programming Applications	9:00–12 00	Stephen F. Austin
FA4	Simulation	9:00–12:00	W.B. Travis
FA5	Reliability and Maintainability	9:00–12:00	Vaquero
FA6	Measurements of Effectiveness in Health, etc.	9:00–12:00	Alamo
FA7	Simultaneous Session IX	9:00–10:15	Ballroom Foyer
FA8	Simultaneous Session X	10:30–11:45	Ballroom Foyer

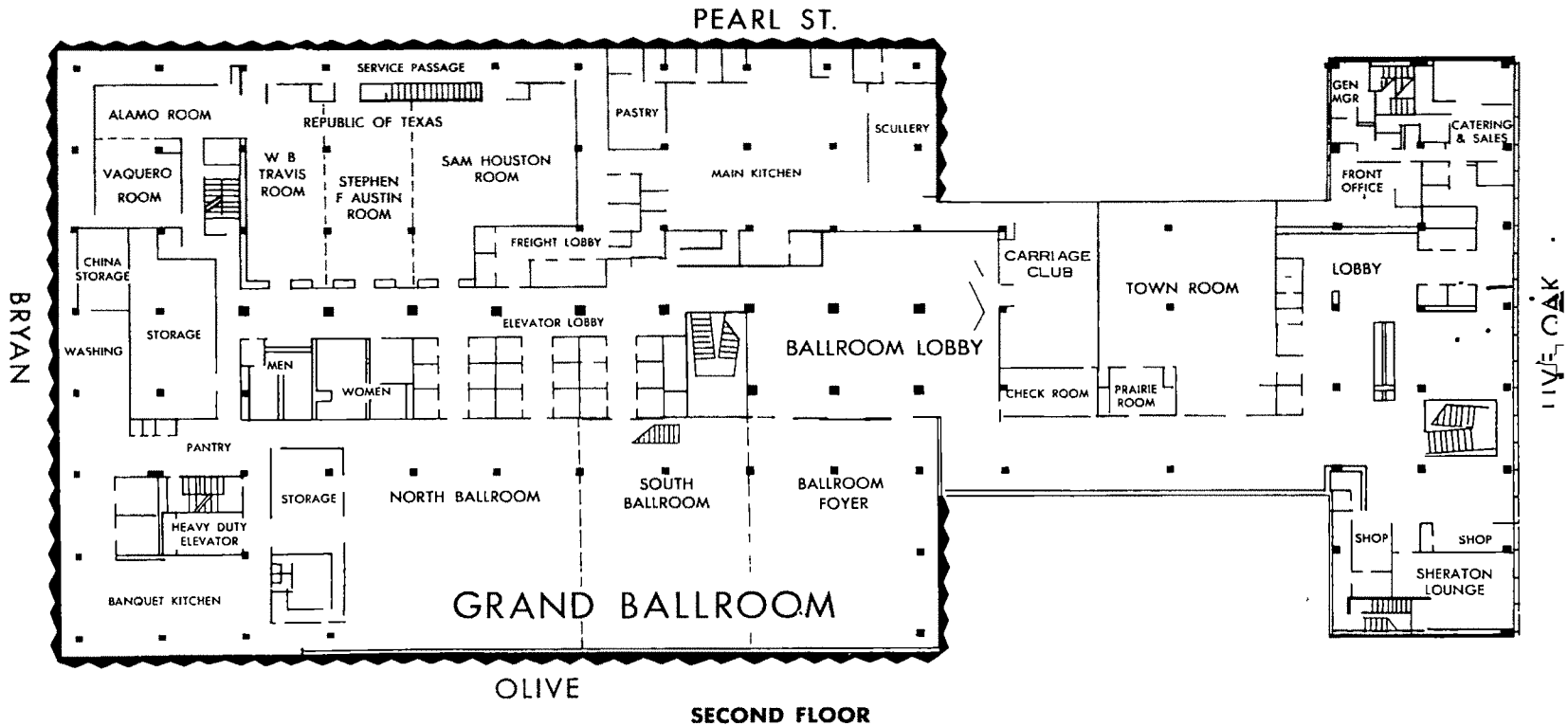
	Friday, May 7	PM	Room
FP1	Space Sciences	2:00–5:00	Pioneer
FP2	Operations Research in Health and Welfare	2:00–5:00	Sam Houston
FP3	Systems Analysis in Government	2:00–5:00	Stephen F. Austin
FP4	Information Storage and Retrieval	2:00–5:00	W.B. Travis
FP5	Educational Science	2:00–5:00	Vaquero
FP6	Optimization Theory	2:00–5:00	Alamo
FP7	Simultaneous Session XI	2:00–3:15	Ballroom Foyer
FP8	Simultaneous Session XII	3.30–4:45	Ballroom Foyer

Other Room Assignments (May 5–7)

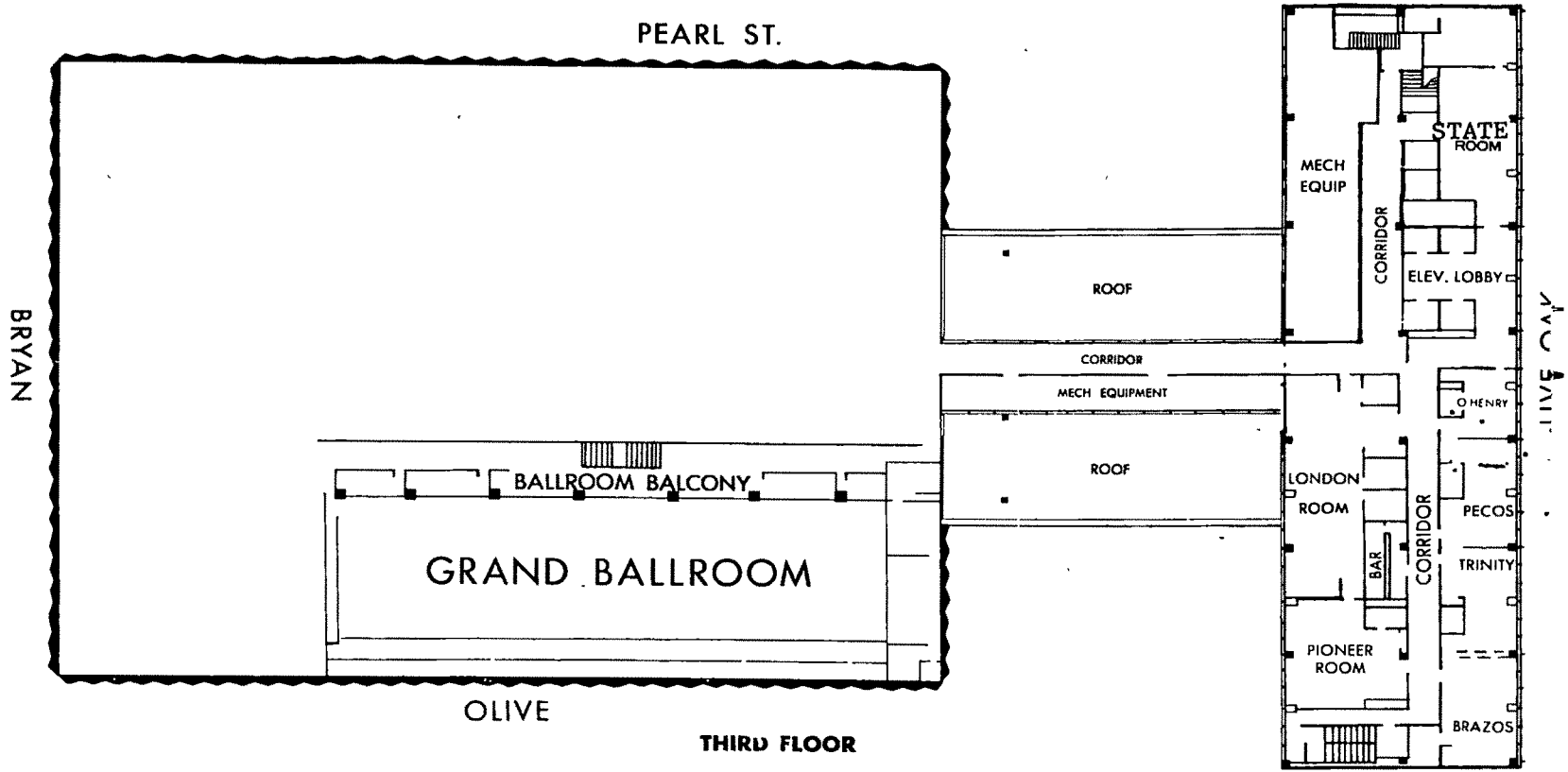
Prairie	Conference Headquarters
Pecos	ORSA Council Meeting
State	Ladies' Hospitality Room
London	Ladies' Fashion Show
Trinity*	Technical Sections Meeting Room
O'Henry*	Room for Informal Group Discussion
Brazos*	Room for Informal Group Discussion
Check	Display of Papers

*These rooms must be reserved by the appropriate ORSA Technical Section or a discussion leader who wishes to discuss any topic of interest. Reservations should be made through:

Professor William P. Pierskalla
Department of Industrial Engineering
Northwestern University
Evanston, Illinois 60201



SECOND FLOOR



SHERATON DALLAS HOTEL

PROGRAM

of the

39th National Meeting

• • •

Operations Research Society of America

SHERATON-DALLAS HOTEL DALLAS, TEXAS

May 5–7, 1971

WEDNESDAY AM, MAY 5 Pioneer Room

Session: WA1 9:00–12:00
Queueing

Chairman: U. NARAYAN BHAT
Computer Science/
Operations Research Center,
Southern Methodist University,
Dallas, Texas 75222

*WA1.1 Non-Equilibrium Theory of Queueing Systems, *N.U. PRABHU, Cornell University and Mathematics Research Center, University of Wisconsin, Madison, Wisconsin 53706.*

*WA1.2 A Survey of Research in Optimal Dynamic Control of Queueing Systems, *THOMAS B. CRABILL, School of Business, University of North Carolina, Chapel Hill, North Carolina 27514.*

*WA1.3 Convexity in the Descriptive Distributions of Congestion Systems, *JULIAN KEILSON, Department of Statistics and School of Business Administration, The University of Rochester, Rochester, New York 14627.*

*WA1.4 Busy Period Analysis of a Time-Sharing System Modeled as a Semi-Markov Process, *U. NARAYAN BHAT and RICHARD E. NANCE, Computer Science/Operations Research Center, Southern Methodist University, Dallas, Texas 75222.*

WA1.5 Cyclic Queues with Bulk Arrivals, *IGAL ADIRI, IBM Thomas J. Watson Research Center (on leave of absence from Technion, Israel), Yorktown Heights, New York.*

WA1.6 Control of Queues, *S.SUBBA RAO and K.P.K. NAIR, Department of Operations Research, Case Western Reserve University, Cleveland, Ohio 44106.*

WA1.7 On the Relation Between Customer and Time Averages in Queues with Some Applications, *SHELBY BRUMELLE, Faculty of Commerce and Business Administration, University of British Columbia, Vancouver, British Columbia, Canada.*

WEDNESDAY AM, MAY 5 **Sam Houston Room**

Session: WA2 9:00–12:00
Military Applications
(Sponsored by Military Applications Section)

Chairman: ERWIN BAUMGARTEN
Center for Naval Analyses,
1401 Wilson Boulevard,
Arlington, Virginia 22209

*WA2.1 An Analysis of Preferential Area ABM Defenses, *STEPHEN B. DEUTSCH, Institute for Defense Analysis, Arlington, Virginia 22202.*

*WA2.2 The Effect and Use of Air Power in the Middle East, *JOSEPH ALON, Embassy of Israel, Washington, D.C.*

*WA2.3 The Requirement for Air Force Tactical Forces in the 1980's, *RICHARD G. RHOADES, Office of Operations Analysis, Tactical Air Command, Langley Air Force Base, Virginia 23366.*

*WA2.4 A Simulation Model for Scheduling Randomly Occurring Airlift Demands, *DAVID T.H. CAMPBELL, Navy Weapon Systems Analysis Office, Marine Corps Air Station, Quantico, Virginia 22134.*

WEDNESDAY AM, MAY 5 **Stephen F. Austin Room**

Session: WA3 9:00–12:00
Integer Programming

Chairman: FRED GLOVER
School of Business,
University of Colorado,
Boulder, Colorado 80302

*WA3.1 Corner Polyhedra and Related Inequalities, *RALPH E. GOMORY, IBM Thomas J. Watson Research Center, Box 218, Yorktown Heights, New York 10598.*

*WA3.2 Data Manipulation of Integer Programming Problems, *G.ANTHONY GORRY and JEREMY F. SHAPIRO, Massachusetts Institute of Technology, Cambridge, Massachusetts, and LAURENCE A. WOLSEY, University of Manchester, Manchester, England.*

*WA3.3 Primal Methods with Convexity Cuts, *RICHARD D. YOUNG, Departments of Economics and Mathematical Sciences, Rice University, Houston, Texas 77001.*

*WA3.4 Integer Programming and Convex Analysis, *EGON BALAS, Graduate School of Industrial Administration, Carnegie-Mellon University, Pittsburgh, Pennsylvania 15213.*

*WA3.5 Transformation of Integer Programs to Knapsack Problems, *GORDON H. BRADLEY, Administrative Sciences Department, Yale University, New Haven, Connecticut 06520.*

WA3.6 Constraint Classification in Zero-One Integer Programming, *V.J. BOWMAN, Graduate School of Industrial Administration, Carnegie-Mellon University, Pittsburgh, Pennsylvania 15213.*

WA3.7 Enumerative Algorithms for Nonlinear Extreme Point Mathematical Programming Problems, *H.R. LOVE, Department of Mathematics, University of Prince Edward Island, Charlottetown, Prince Edward Island, Canada; M.KIRBY, Department of Mathematics, Dalhousie University, Halifax, Nova Scotia, Canada, and KANTI SWARUP, Faculty of Mathematics, University of Delhi, India.*

WA3.8 A Mixed Integer Programming Algorithm, *A. RIESCO, Department of Industrial Engineering, University of Puerto Rico, Mayaguez, Puerto Rico 00708, and M.E. THOMAS, Department of Industrial and Systems Engineering, University of Florida, Gainesville, Florida 32601.*

WEDNESDAY AM, MAY 5 W.B. Travis Room

Session: WA4 9:00–12:00
Manpower Cost Effectiveness Studies
(Sponsored by: Cost Effectiveness Section)

Chairman: HAROLD WOOL
Office of Research,
U.S. Department of Labor,
Washington D.C.

*WA4.1 Problems and Issues in the Evaluation of Manpower Programs: An Overview, *MICHAEL E. BORUS, The Ohio State University, Columbus, Ohio.*

*WA4.2 A Cost-Effectiveness Analysis of the In–School and Summer Neighborhood Youth Corps, *ERNST W. STROMSDORFER, Indiana University, Bloomington, Indiana 47401.*

*WA4.3 An Assessment of Four Manpower Programs, *PETER S. BARTH, Office of Research and Development, Manpower Administration, Department of Labor, Washington, D.C.*

*WA4.4 Towards an Optimum Military Personnel Recruitment and Retention Policy, *M.LANDO and D. O'NEILL, Center for Naval Analyses, 1401 Wilson Boulevard, Arlington, Virginia 22209.*

WEDNESDAY AM, MAY 5 Vaquero Room

Session: WA5 9:00–12:00
Operations Research in the Administration of Justice

Chairman: RICHARD C. LARSON
Room 9-226 CAES,
Massachusetts Institute of Technology,
Cambridge, Massachusetts 02139

*WA5.1 Models of the Production and Deterrence of Crime, *ALFRED BLUMSTEIN, Urban Systems Institute, Carnegie-Mellon University, Pittsburgh, Pennsylvania 15213.*

*WA5.2 A Systems-Analytic View of Criminal Justice in Virginia, *DUNCAN BAILEY, LEE McPHETERS, Crime Prevention Systems Corporation, P.O. Box 119, Blacksburg, Virginia 24060, and CHARLES SCHOTTA, Economics Department, Virginia Polytechnic Institute and State Universtiy, Blacksburg, Virginia 24061.*

*WA5.3 Simulation Model Of a Municipal Detective System, *JOSEPH FOLK, Room 24-318, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139.*

*WA5.4 Operations Research at the St. Louis Metropolitan Police Department, *NELSON B. HELLER, Metropolitan Police Department, 1200 Clark Street, St Louis, Missouri 63103.*

*WA5.5 Quantitative Models of Criminal Courts, *JOHN B. JENNINGS, New York City RAND Institute, 545 Madison Avenue, New York, New York 10022.*

*WA5.6 Criminal Justice Analyses in New York City, *PETER R. GRAY, Criminal Justice Coordinating Council, City of New York, Office of the Mayor, New York, New York 10007.*

P9546

WEDNESDAY AM, MAY 5 **Alamo Room**

Session: WA6 9:00–12:00
Production Scheduling, Planning and Forecasting

Chairman: MICHAEL M. CONNORS
IBM Scientific Center,
1930 Century Park West,
Los Angeles, California 90067

*WA6.1 Chaos and Control, *ROBERT G. BROWN, IBM, 112 East Post Road, White Plains, New York 10601.*

*WA6.2 Dynamic Models for Capacity Expansion and Location, *DONALD ERLENKOTTER, Graduate School of Management, University of California, Los Angeles, California 90024.*

*WA6.3 A Decomposition Algorithm for Arborescence Inventory Systems, *BASIL A. KALYMON, Graduate School of Business Administration, University of California, Los Angeles, California 90024.*

*WA6.4 The Roles of the Man and the Computer in Production Planning, *CURTIS H. JONES, Graduate School of Business Administration, Harvard University, Boston, Massachusetts 02163.*

WA6.5 Production Scheduling Using Network Flows Under Uncertainty, *GORDON P. WRIGHT, Krannert Graduate School of Industrial Administration, Purdue University, Lafayette, Indiana, and JUAN PRAWDA, Graduate School of Business Administration, Tulane University, New Orleans, Louisiana.*

WA6.6 Deterministic Production Planning with Concave Costs and Capacity Constraints, *MICHAEL FLORIAN and MORTON KLEIN, Operations Research Group, Columbia University, New York, New York.*

WA6.7 Manpower Planning for Aircraft Manufacturing Operation, *H.F CHIANG and C.E. CLARK, JR., Northrop Corporation, Aircraft Division, Organization 5305, Zone 4, 3901 West Broadway, Hawthorne, California 90250.*

WEDNESDAY AM, MAY 5 **Ballroom Foyer**

Session: WA7 9:00–10:15
Simultaneous Session I

Chairman: DONALD M. TOPKIS
Department of Industrial Engineering
and Operations Research,
University of California,
Berkeley, California 94720

WA7.1 Poisson Processes in Random Environments, *RICHARD F. SERFOZO, Systems Engineering and Operations Research, Syracuse University, Syracuse, New York 13210.*

WA7.2 Regression Analysis of Class Differences, *BARR ROSENBERG, School of Business Administration, University Of California, Berkeley, California 94720.*

WA7.3 Interactions of Cost, Reliability and Performance Factors in Advanced Space Systems, *DAVID K. BIVENS, Mathematica, Inc., 1 Palmer Square, Princeton, New Jersey 08540.*

WA7.4 Optimum Lot Sizes for a Shop-Warehouse System, *MOHAMED E. TAYMOUR, Technical Coordination and Planning, Owens–Illinois, Inc., Technical Center, P.O. Box 1035, Toledo, Ohio 43601.*

WA7.5 Stochastic Interference in Item Processing Systems, *ROBERT H. BEEDE, Avco Systems Division, 201 Lowell Street, Wilmington, Massachusetts 01887.*

WA7.6 A Routing Problem in City Solid Waste Collection, *RICHARD M. [illegible] VIDA and JATINDER N.D. GUPTA, Department of Industrial and Systems Engineering, The University of Alabama in Huntsville, P.O. Box 1247, Huntsville, Alabama 35807.*

WA7.7 Surveillance of Surface Water Quality: Design and Operation of Data Networks, *CHESTER C. KISIEL. Hydrology and Water Resources Office, The University of Arizona, Tucson, Arizona 85721.*

WA7.8 Sequencing Aircraft at an Air Terminal, *JOSEPH S. MATNEY and WALTER C. GIFFIN, Industrial Engineering Department, The Ohio State University, Columbus, Ohio 43210.*

WA7.9 Shortest Route Subject to Improvements through Dynamic Programming, *S.P. BANSAL, Department of Mathematics, A.R.S.D. College, Dhaula Kuan, Delhi University, New Delhi 23, India, and S.KUMAR, Department of Mathematics, Royal Melbourne Institute of Technology, 124 La Trobe Street, Melbourne, Vic. 3000, Australia.*

WA7.10 A Decision Model for Evaluating Potential Change in Instructional Programs, *J. P. AMOR and JAMES S. DYER, The Graduate School of Business Administration, The University of California, Los Angeles, California.*

WA7.11 Risk Properties of Multiattributed Utility Functions, *RALPH L. KEENEY, Operations Research Center, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139.*

WA7.12 Evaluation by Simulation Saves Construction Dollars, *AUSTIN E. BRANT, JR., and PATRICK J. McAWARD, JR., Tippetts--Abbett-McCarthy-Stratton, 604 Avenue H East, Suite 201, El Patio East Building, Arlington, Texas 76011.*

WA7.13 Computer-Based Laboratories for Teaching O.R. and Statistics, *AMRIT L. GOEL and P. NANDA, Department of Industrial Engineering, Syracuse University, Syracuse, New York 13210.*

WA7.14 Systems Evaluation by Discrete Markov Event Chain Analysis, *GERALD R. HARP, Phillips Petroleum Company, Bartlesville, Oklahoma 74003.*

WA7.15 Systems Analysis in the Courts, *WILLIAM H. BLEUEL, Stochastic Systems Research Corporation, Suite 900, One East Main Street, Rochester, New York 14614.*

WA7.16 On the Solution to Lanchester-Type Equations with Variable Coefficients, *JAMES G. TAYLOR, Naval Postgraduate School, Monterey, California 93940.*

WA7.17 The Use of Network Theory in Determining Corporate Planning Strategies, *GAYLE C. FOHRELL, The Weyerhaeuser Company, Tacoma, Washington 98401.*

WA7.18 A Model for Interurban Travel in the United States, *PHILIP M. PEARSON, Office of Systems Analysis and Information, U.S. Department of Transportation, Washington, D.C.*

WA7.19 A Lagrangian Formulation of the Journal Selection Model, *D.H. KRAFT, School of Library and Information Services, University of Maryland, College Park, Maryland 20742, and T.W. HILL, JR., School of Industrial Engineering, Purdue University, Lafayette, Indiana 47907.*

WA7.20 Linear Programming Applied to the Analysis of Variance of Designed Experiments, *FRED L. CASHLER, Shell Oil Company, Houston, Texas, and BEN T. RHODES, JR., University of Houston, Houston, Texas.*

(Continued)

WA7.21 Simple Procedure for Constructing Orthogonal Latin Squares using Congruence Relations, *MOHAMMED M. SHAMMA, College of Business Administration, University of Cincinnati, Cincinnati, Ohio 45221.*

WEDNESDAY AM, MAY 5 **Ballroom Foyer**

Session: WA8 10:30–11:45
Simultaneous Session II

Chairman. DONALD M. TOPKIS
Department of Industrial Engineering
and Operations Research,
University of California,
Berkeley, California 94720

WA8.1 Economic Simulation in the Timber Industry, *ROBERT M. CLINKSCALE, JR., Booz, Allen Public Administration Services, Inc., 1025 Connecticut Avenue, N.W., Washington, D.C. 20036.*

WA8.2 Some Experimental Results Using Variance Reduction Techniques in Simulation, *FRANK A. DUNN, Esso Math and Systems, Inc., 394 Beverly Boulevard, Upper Darby, Pennsylvania 19082.*

WA8.3 A Mission-Oriented Reliability Model, *ROBERT H. GRUHL, Consultec, Inc., 2351 Research Boulevard, Rockville, Maryland 20850.*

WA8.4 Maximal Steady State Flow Characteristics for an Idealized Railway System, *DIETRICH R. BERGMAN, Department of Industrial Engineering and Operations Research, Wayne State University, Detroit, Michigan 48202.*

WA8.5 A Systems Model for Energy Management, *JACK BYRD, JR., and R. DAVID HAYNES, Department of Industrial Engineering, West Virginia University, Morgantown, West Virginia 26506.*

WA8.6 Measuring Prices in the Computer Time-Sharing Market, *ROBERT T. RILEY, Department of Quantitative Analysis, University of Cincinnati, Cincinnati, Ohio 45221.*

WA8.7 Optimal Service Policies for Solid Waste Treatment Facilities, *HELMAN I. STERN, Systems Engineering Division, Rensselaer Polytechnic Institute, Troy, New York.*

WA8.8 Analysis of Management Decision Making in Information System Design, *MICHAEL E. COHEN, CONSAD Research Corporation, 5600 Forward Avenue, Pittsburgh, Pennsylvania 15217.*

WA8.9 The Comparative Value of Artillery and Air Support in World War II, *ROBERT McQUIE, U.S. Postal Service, Planning and Marketing, 13th and Pennsylvania Avenue, N.E., Washington, D.C.*

WA8.10 Dynamic Programming in the Allocation and Management of Graveyards, *Q.A.M.M. YAHYA, 96 Bangalore Town, Karachi, West Pakistan.*

WA8.11 Determining the N Most Vital Links in a Flow Network, *S.H. LUBORE, The Mitre Corporation, McLean, Virginia 22101; H.D. RATLIFF, University of Florida, Gainesville, Florida, and G.T. SICILIA, The Mitre Corporation, McLean, Virginia 22101.*

WA8.12 Contingency Planning at a Bank Holding Company, *JOSEPH E. MICHINI, Marine Midland Services Corporation, 110 Seneca Street, Buffalo, New York 14203.*

WA8.13 Computer Network Simulator, *JOHN L. REDDING, Naval Ship Research and Development Center, Carderock, Maryland 20034.*

WA8.14 A Simplicial Method for Nonlinear Programming, *AMILCAR S. GONÇALVES, Universidade De Coimbra, Faculdade De Ciencias, Coimbra, Portugal.*

WA8.15 Economic Model of a Two-Level Material Distribution System, *WILLIAM SHELSON, Operations Research Group, Ontario Hydro Research Division, 800 Kipling Avenue, Toronto 18, Canada.*

WA8.16 Recreation System–Transportation System Interaction Cycle, *RICHARD A. LADD, United States Coast Guard Academy, New London, Connecticut 06320.*

WA8.17 A Markovian Model of Patient Flow in Comprehensive Health Care Projects, *BJORN LARSEN, Systems Development Project, University of Minnesota, Minneapolis, Minnesota 55414.*

WA8.18 Theory and Application of End-Product Pipeline Problems, *MARSHALL ROSE, Xerox Corporation, Rochester, New York.*

WA8.19 A Coordinate Oriented Algorithm for the Traveling Salesman Problem, *JOSEPH S. GREENE, SR., Drury College, Springfield, Missouri 65802, and A.K. RIGLER, Computer Science Department, University of Missouri-Rolla, Rolla, Missouri.*

WA8.20 The Estimation of Probability Densities and Cumulatives for Computer Modeling, *MELVIN O. BRAATEN and SHANTILAL JAIN, Industrial Engineering, University of Missouri-Columbia, Columbia, Missouri 65201.*

WA8.21 Bayesian Control Policies for Stochastic Processes, *PHILLIP L. CARTER, Department of Management, Graduate School of Business Administration, Michigan State University, East Lansing, Michigan 48823.*

WEDNESDAY PM, MAY 5 **Sam Houston Room**

Distinguished Lecture I 1:00–1:50

HARVEY M. WAGNER
Department of Administrative Sciences,
2 Hillhouse Avenue,
Yale University,
New Haven, Connecticut 06520

The ABC's of O.R.

The talk will present an overview of the Achievements, Beliefs, and Content of Operations Research. Specific attention will be turned to four activities. The first is the application of Operations Research methodology to the solution of critical managerial problems. The primary context will be that of private enterprise. The second is the development of Operations Research theory. The research outpourings will include and distinguish among the professional societies' publications, doctoral theses and faculty research. The third activity is the training of operations researchers, both practitioners and future educators. And the fourth is the purposeful guidance of Operations Research professional societies.

For each of the above four activities, the talk will contain a brief summary of the progress that has been made. It will assess present-day Operations Research and also will provide some explanatory hypotheses for this progress. In addition, the talk will speculate on what kinds of further advances are likely to ensue. These prognoses will be examined in terms of their managerial and social consequences.

WEDNESDAY PM, MAY 5 **Pioneer Room**

Session: WP1 2:00–5:00
Use of Computers in Industry: Portfolio Selection and Financial Management

Chairman: JULIUS ARONOFSKY
Graduate School of Business,
Southern Methodist University,
Dallas, Texas 75222

Panel: DOUGLASS M. PARNELL, JR., *Computer Technology, Inc., Dallas, Texas,* E. HODSON THORNBER, *Catallactics Corporation, Chicago, Illinois,* ROBERT E. HUDSON, JR., *Mellon National Bank and Trust, Pittsburgh, Pennsylvania.* ROBERT FRAME, *School of Business Administration, Southern Methodist University, Dallas, Texas 75222* and MICHAEL SHEGDA, *Lybrand Ross Bros., & Montgomery, 2 Broadway, New York, New York.*

This session will be organized as a panel discussion where questions and comments by the audience will be encouraged. Rather than open up the broad subject of general computer usage in industry, a more selective topic has been chosen for in-depth discussion and review.

The central theme will be the use of computers by the financial community in areas of investing and managing funds.

This subject area will be examined by practitioners in the field who come with a broad background of experience. The topics include: criteria for evaluating individual investments, selecting a portfolio, evaluating performance of a fund, maintaining accounting and tax records for individual customers, use of program packages, and the role of the computer.

The panelists will be asked to express their views on some relevant part of the subject area. They may want to comment on current practices, the state of the art, or how computers will be used in the future.

WEDNESDAY PM, MAY 5 **Sam Houston Room**

Session: WP2 2:00–5:00
Computer Systems Analysis

Chairman: LEONARD KLEINROCK
Department of Engineering,
University of California,
Los Angeles, California 90024

***WP2.1** Multiprogramming Models, *DONALD P. GAVER, Department of Statistics, Carnegie-Mellon University, Pittsburgh, Pennsylvania.*

***WP2.2** Optimal Modes of Multiprogramming, *PETER J. DENNING, Department of Electrical Engineering, Princeton University, Princeton, New Jersey.*

***WP2.3** Processor-Sharing Queueing Models of Mixed Scheduling Disciplines for Time-Shared Systems, *LEONARD KLEINROCK and R.R. MUNTZ, Computer Science Department, University of California, Los Angeles, California 90024.*

***WP2.4** Routing in Computer Networks, *H. FRANK and W. CHOU, Network Analysis Corporation, Beechwood, Old Tappan Road, Glen Cove, New York 11542.*

WEDNESDAY PM, MAY 5 **Stephen F. Austin Room**

Session: WP3 2:00–5:00
Defense Non-defense Tradeoff Analysis
(Sponsored by: Cost Effectiveness Section)

Chairman: ROBERT KUPPERMAN
Office of Emergency Planning,
Washington, D.C.

The changing socio-economic environment has caused a shift in domestic problems from the long held emphasis upon military and space endeavors. This session will explore the policy considerations involved in integrating the aero-space industry and the allied technical community and to the software and hardware considerations for urban, educational, and environmental problems. Speakers will address themselves to the current legislative environment such as the McGovern Bill as well as the financial and technical considerations of steering the aero-space community toward domestic issues.

WEDNESDAY PM, MAY 5 **W.B. Travis Room**

Session: WP4 2:00–5:00
Dynamic Programming and Markov Decision Processes

Chairman: ERIC V. DENARDO
Department of Administrative Sciences,
Yale University,
New Haven, Connecticut 06520

*WP4.1 Average Cost Criterion in Markov Decision Processes, *M.J. MAGAZINE and PRAGATI SEHGAL, Department of Industrial Engineering, North Carolina State University, Raleigh, North Carolina 27607.*

*WP4.2 Lyapunov Functions for Markovian Decision Processes, *PAUL J. SCHWEITZER, Technion-Israel Institute of Technology, Haifa, Israel.*

*WP4.3 Maximal Average-Reward Policies for a Class of Semi-Markov Decision Processes with Arbitrary State and Action Space, *STEVEN A. LIPPMAN, Graduate School of Business Administration, University of California, Los Angeles, California 90024.*

*WP4.4 Markov Renewal Programs with Unknown Parameters, *B.L. FOX and J.E. ROLPH, The RAND Corporation, Santa Monica, California 90406.*

WP4.5 Deterministic Discrete Dynamic Programming with Discount Factor Greater than One, *YVO DIRICKX, Department of Administrative Sciences, Yale University, New Haven, Connecticut 06520.*

WP4.6 The Optimal Admission Policy to a Multiserver Queue with Finite Horizen, *HAMILTON EMMONS, Department of Operations Research, College of Engineering, Cornell University, Ithaca, New York 14850.*

WP4.7 A Generalized Recursive Algorithm for a Class of Non-stationary Regeneration (Scheduling) Problems, *FRED GLOVER, School of Business, University of Colorado, Boulder, Colorado 80302, and THEODORE D.KLASTORIN, Graduate School of Business, University of Texas at Austin, Austin, Texas 78712.*

WP4.8 On a Two-Dimensional Resource Allocation Problem, *JONATHAN S. YORMARK, The RAND Corporation, Santa Monica, California 90406, and NORMAN R. BAKER, School of Industrial and Systems Engineering, Georgia Institute of Technology, Atlanta, Georgia 30332.*

WEDNESDAY PM, MAY 5 **Vaquero Room**

Session: WP5 2:00–5:00
Urban Transportation
(Sponsored by. Transportation Science Section)

Chairman: DANIEL ROOS
Department of Civil Engineering,
Massachusetts Institute of Technology,
Cambridge, Massachusetts 02139

Typically, many proposed operations research techniques are considerably modified when they are implemented in practice due to social, political, economic and institutional constraints. This series of papers examines initial theoretical work and shows how and why it was modified during development, implementation, and operation. The observed data gained from operational experience are compared with the predicted results of the theoretical models.

***WP5.1** An Application of Vehicle Scheduling to School Transportation, *WILLIAM L. CAUDLE, Teknatronic Applications, Inc., 412 Main Street, Lafayette, Indiana 47901.*

***WP5.2** A Dynamic Vehicle Merging Control System, *H. L. GROGINSKY, Advanced Development Laboratory, Raytheon Company, Weyland, Massachusetts.*

***WP5.3** Technological Innovation in Urban Transportation – The Role of the Federal Government, *ROBERT A. HEMMES, Office of Program Demonstration, Urban Mass Transportation Administration, U.S. Department of Transportation, Washington, D.C.*

***WP5.4** Implementation of Computer Algorithms for the Dial-A-Bus System, *NIGEL WILSON and JOSEPH SUSSMAN, Department of Civil Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139.*

***WP5.5** Monitor-CTA–An Automatic Vehicle Monitoring System, *RALPH W. TRACY, Chicago Transit Authority, Merchandise Mart Plaza, P.O. Box 3555, Chicago, Illinois 60654, and WILLIAM M. BORMAN, Transportation Resources, Motorola, 1301 East Algonquin Road, Schaumburg, Illinois 60172.*

WEDNESDAY PM, MAY 5 **Alamo Room**

Session: WP6 2:00–5:00
Student Papers

Chairman: ROBERT M. THRALL
Department of Mathematical Sciences,
Rice University,
Houston, Texas 77001

The two winning and the four honorable mention student papers will be taken from the list below. The remaining eighteen papers will be distributed among the twelve Simultaneous Sessions.

S1 A Mathematical Model of a Plant Leaf, *JAMIL AHMED, Department of Industrial Engineering, Texas A&M University, College Station, Texas 77843.*

S2 Gradient Projection Algorithm Applied to a Least Time Problem in Physics, *M. AFTAB ALAM, Texas Instruments, Inc., P.O. Box 5621, M.S. 965, Dallas, Texas 75222.*

S3 A New Theory of Optimal Investment, *DONALD C. AUCAMP, Department of Applied Mathematics and Computer Science, Washington University, St. Louis, Missouri 63130.*

S4 An Analytical Theory of Risk Versus Return, *DONALD C. AUCAMP, Department of Applied Mathematics and Computer Science, Washington University, St. Louis, Missouri 63130.*

S5 Multiple Deferred State Sampling with Tightened Conditional Acceptance, *R.C. BAKER, Department of Industrial Engineering, Texas A&M University, College Station, Texas 77843.*

S6 Sequential Test Procedure with Delayed Observations, *RAU C. CHANG, Department of Industrial Engineering and Operations Research, School of Engineering and Science, New York University, University Heights, Bronx, New York 10453.*

S7 Stochastic Single Commodity Network Flow, *J.W. CRAWFORD, Bell Telephone Laboratories, Inc., Whippany Road, Whippany, New Jersey 07981.*

S8 Formulation of the Dynamic Deterministic Inventory Model as a Branch and Bound Programming Problem, *RICHARD H. DEANE, School of Industrial Engineering, Purdue University, Lafayette, Indiana.*

S9 Aircraft Rearming and Refueling Simulation Model, *ROBERT D. DROWLEY, CWDS-03, USAF Academy, Colorado 80840, and DAVID O. TROTTER, CWDS-22, USAF Academy, Colorado 80840.*

S10 Interpreting Accident Statistics, *JOSEPH FERREIRA, JR., Operations Research Center, Massachusetts Institute of Technology, Room 24-215, Cambridge, Massachusetts 02139.*

S11 Final Report on the Simulation of the Production Run of the Magic Tee at Microwave Development Laboratory, *ALAN J. GOLDBERG, Department of Industrial Engineering and Operations Research, Marston Hall, University of Massachusetts, Amherst, Massachusetts 01002.*

S12 Nonlinear Optimization with Upper and Lower Bounds, *V.E. HUCK-FELDT, Department of Operations Research, Case Western Reserve University, Cleveland, Ohio 44106.*

S13 A Dynamic Resources Planning Model with Technological and Resource Changes, *L.L. JAYARAMAN, Management Science Center, Wharton School of Finance, Philadelphia, Pennsylvania 19104.*

S14 A Branch and Bound Method for the Fixed Charge Transportation Problem, *MARY W. COOPER, Advances Technology Center, P.O. Box 6144, Dallas, Texas 75222.*

S15 Time Sharing with an Explicit Priority Queuing Discipline, *CYRUS RUSTAM MEHTA, Massachusetts Institute of Technology, E53-376 50 Memorial Drive, Cambridge, Massachusetts 02139.*

S16 CAINS—A Computer Aided Instruction System, *L.J. MILLER, CWDS-20, USAF Academy, Colorado 80840.*

S17 The Generalized Lagrange Multiplier Technique Applied to an Inventory Problem, *S.C. MOORE, Computer Science/Operations Research Center, Southern Methodist University, Dallas, Texas 75222.*

S18 Sequential Decisions Over a Finite Collection of Mutually Independent Markov Chains, *STEVEN NAHMIAS, Department of Industrial Engineering and Management Science, Northwestern University, Evanston, Illinois 60201.*

S19 Go-Stop; Global Optima by a Sequential Testing Optimization Procedure, *THEODORE C. ROBBINS, Computer Science/Operations Research Center, Southern Methodist University, Dallas, Texas 75222.*

(Continued)

S20 The Use of Experimental Design in the Control of Continuous Processes, *CASS SCHICHTLE, 411 Tee Drive, Bryan, Texas 77801.*

S21 Optimization of a Production Flow Model, *JAY D. SHERMAN, Department of Industrial Engineering, Texas A&M University, College Station, Texas 77843.*

S22 Terminal City Defense, *KENNETH C SHUMATE, Box 2810, Naval Postgraduate School, Monterey, California 93940.*

S23 The Need for a Fourth Jetport Serving the New York Metroplex—A Systems Study, *SIDNEY J. STERLING, US Army Electronics Command, Fort Monmouth, New Jersey.*

S24 Approximations to Optimal Policies in a Stationary Multicommodity Inventory Model with Set-Up Cost, *WILLIAM DENNIS WACKER, Department of Mathematics, Parks College of Aeronautical Technology, Cahokia, Illinois 62206.*

WEDNESDAY PM, MAY 5 **Ballroom Foyer**

Session: WP7 2:00–3:15
Simultaneous Session III

Chairman: GORDON P. WRIGHT
Krannert School of
Industrial Administration,
Purdue University,
Lafayette Indiana 47907

WP7.1 Alternative Generation Using Mixed Integer Programming, *DAVID W. ALDRICH, C/O Operations Research, Weyerhaeuser Company, Tacoma, Washington 98401.*

WP7.2 Using Branch Classification in Forecasting Bank Volume, *BARR ROSENBERG, School of Business Administration, University of California, Berkeley, California, and RONALD J LANSTEIN, Wells Fargo Bank, Management Science Department, San Francisco, California*

WP7.3 Analysis of CPU Dispatching Rules for Batch Multiprogramming Computer Systems, *D.L. BOYD, Department of Computer Science, University of Minnesota, Minneapolis, Minnesota, and D.L. EPLEY, Department of Electrical Engineering, University of Iowa, Iowa City, Iowa.*

WP7.4 Process Optimization for Water Pollution Control, *CHIA SHUN SHIH, DUANE J. WRAY, G.A. ELLIFF, and W.L. MEIER, JR., Industrial Engineering Department, Texas A&M University, College Station, Texas 77843.*

WP7.5 Scientific Design of a Hospital Training System, *ROSALIE KASABA and BECKY ABATO, Holy Cross Hospital, San Fernando, California, and CARL E. HOPKINS, UCLA School of Public Health, Los Angeles, California.*

WP7.6 Markov Decision Models in the Design of Structural Systems for Repeated Sequences of Random Loading, *ERIK H. VANMARCKE, Department of Civil Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139.*

WP7.7 A Monte Carlo Simulation for Decision Tree Analysis, *JERRY B. WILLIAMS, Research Division, The Boeing Company, Seattle, Washington 98124, and JAMES C. GOODWIN, Computer Services Division, The Boeing Company, Seattle, Washington 98124.*

WP7.8 Solution of Mixed Zero-One Linear Programs by Ranking the Extreme Points, *HAMDY A. TAHA; Department of Industrial Engineering, University of Arkansas, Fayetteville, Arkansas 72701.*

WP7.9 A Scoring Model Replacement for L.P., *ISADORE M. KLAHR, Management Sciences Group, PPG Industries, Inc., Glass Research Center, P.O. Box 11472, Pittsburgh, Pennsylvania 15238, and J.V. POOLA, Research Computer Operations, PPG Industries, Inc., Glass Research Center, P.O. Box 11472, Pittsburgh, Pennsylvania 15238.*

WP7.10 Economic Capacity Planning for Variable Demand, *CARL B. ESTES, Industrial Engineering and Management Department, Oklahoma State University, Stillwater, Oklahoma 74074.*

WP7.11 Empirically Derived Inventory Decision-Making Models: Their Uses and Economic Consequences, *STANLEY T. HARDY, Faculty of Management Sciences, The Ohio State University, Columbus, Ohio.*

WP7.12 A Lambda-Form for Nonseparable Programming, *PHILIP B. ZWART, Department of Applied Mathematics and Computer Science, Washington University, St. Louis, Missouri 63130.*

WP7.13 A Branch and Double-Bound Algorithm for the Multi-Period Capital Budgeting Problem, *F. OCHOA-ROSSO, IPESA Corporation, México, D.F., Mexico.*

WP7.14 A Heuristic Algorithm for the Vehicle Dispatch Problem, *B.E. GILLETT, Computer Science Department, University of Missouri–Rolla, Rolla, Missouri, and LELAND R. MILLER, Computer Science Department, Bowling Green State University, Bowling Green, Ohio 65401.*

WP7.15 One-Machine Deterministic Job-Shop Scheduling with Precedence Relations and Deferral Costs, *JEFFREY B. SIDNEY, Faculty of Commerce and Business Administration, The University of British Columbia, Vancouver 8, Canada.*

WP7.16 An Analysis of Disruption Costs in Ship Construction (or The Case of the Missing Manhours), *MILIND M. LELE, Harbridge House, Inc., 11 Arlington Street, Boston, Massachusetts 02116.*

WP7.17 Generalized Jet-Select Policies Via Linear Programming, *ROBERT C. FRESE, Department of Applied Mathematics and Computer Science, Washington University, St. Louis, Missouri 63130.*

WP7.18 Parametric Linear Programming Analysis of State Aid Plans to Non-Public Schools, *EDWIN L. HULLANDER, Department of Industrial Engineering, Iowa State University, Ames, Iowa 50010.*

WP7.19 Optimal Capacity Expansion of Pump Station Facilities, *JACK H.M. FERGUSON, Texas Water Development Board, Austin, Texas 78711, and P.A. JENSEN, Department of Mechanical Engineering, University of Texas, Austin, Texas 78712.*

WP7.20 Toward the Stratification and Clustering of Metropolitan Areas, *THOMAS F. GOLOB, EUGENE T. CANTY and RICHARD L. GUSTAFSON, Transportation Research Department, General Motors Research Laboratories, Warren, Michigan 48090.*

WEDNESDAY PM, MAY 5 **Ballroom Foyer**

Session: WP8 3:30–4:45
Simultaneous Session IV

Chairman GORDON P. WRIGHT
Krannert School of
Industrial Administration,
Purdue University,
Lafayette, Indiana 47907

WP8.1 An Approximate Method for Generating Random Variables, *JOHN S. RAMBERG and BRUCE M. SCHMEISER, Department of Industrial and Management Engineering, University of Iowa, Iowa City, Iowa.*

WP8.2 Associative Processors in the Solution of Network Problems, *VINCENT A. ORLANDO and P. BRUCE BERRA, Department of Industrial Engineering, Syracuse University, Syracuse, New York 13210.*

WP8.3 A Quantitative Method for Measuring the Value of Research and Development, *MOHAMED E. TAYMOUR, Technical Coordination and Planning, Owens-Illinois, Inc., Technical Center, P.O. Box 1035, Toledo, Ohio 43601.*

WP8.4 Status Concept of Program Evaluation (SCOPE)—Designed for a Regional Medical Program, *DON J. TRANTOW, Program Assessment Coordinator, Georgia Regional Medical Program, 938 Peachtree Street, N.E., Atlanta, Georgia 30309.*

WP8.5 The Use of the Antithetic in Simulations of Financial Systems, *J.W. COLIN, First National Bank, Box 6031, Dallas Texas 75222.*

WP8.6 A Method for Identifying Optimal Choices in the Development of Educational Media Systems, *ALAN P. WOODRUFF, 101 Western Avenue, Cambridge, Massachusetts.*

WP8.7 QUEST for Information, *S.H. STRAUSS, UNIVAC Federal Systems Division, P.O. Box 6248, San Diego, California.*

WP8.8 Conflict in a Group Binary Decision, *G.A. WHITMORE, Faculty of Management, McGill University, Montreal 112, Canada.*

WP8.9 The Multicommodity Network Flow Model Revised to Include Vehicle Per Time Period and Node Constraints, *HENRY S. WEIGEL and JOHN E. CREMEANS, Research Analysis Corporation, McLean, Virginia 22101.*

WP8.10 On the Decomposition of the Out-of-Kilter Algorithm, *HOANG HAI HOC, Universite de Montreal, Case Postale 6128, Montreal 101, Quebec, Canada,*

WP8.11 On the Cones of Tangents with Application to Optimization Theory, *M.S. BAZARAA, School of Industrial and Systems Engineering, Georgia Institute of Technology, Atlanta, Georgia 30332, and J.J GOODE, School of Mathematics, Georgia Institute of Technology, Atlanta, Georgia 30332.*

WP8.12 Cost Minimization of Refuse Collection Operations: Some Applications of a Basic Model, *MICHAEL J.C. MARTIN and ALAN E. ROTHWELL, College of Commerce and Business Administration, University of Illinois at Urbana-Champaign, Urbana, Illinois 61801.*

WP8.13 Conversational Computerized Statistical Analysis in Business, *JOE BULAT, Burroughs Corporation, Management Systems Development Department, Burroughs at Second Avenue, Detroit, Michigan 48232*

WP8.14 On Cycling in the Transportation Problem, *WLODZIMIERZ SZWARC, Carnegie-Mellon University, Pittsburgh, Pennsylvania 15213.*

WP8.15 A Linear Programming Model for Gas Pipeline Distribution, *KHOSROW ZAMANI, Universite de Technologie, Arya-Mehr, Teheran, Iran.*

WP8.16 The Use of Multiple Routing Techniques for Capacity Restraint Assignments, *BRUNO R. WILDERMUTH, Wilbur Smith and Associates, 4500 Jackson Boulevard, Columbia, South Carolina 29209.*

WP8.17 Large Scale Transportation Problem· Practical Solution for Real Life Problem, *BENJAMIN LEV, Temple University, Philadelphia, Pennsylvania 19122.*

WP8.18 A Family of Marginal Resource Allocation Techniques, *BURTON S. LIEBESMAN, Bell Telephone Laboratories, Room 3B-136, Whippany Road, Whippany, New Jersey.*

WP8.19 Conceptual Data Processing–A New Idea, *GLENN G. FOSTER, Information Systems Division, CASYNDEKAN, Inc., Suite 1070, Holly Sugar Building, Colorado Springs, Colorado 80902.*

WP8.20 Estimating Multidimensional Utility Functions on the Basis of Revealed Preferences. An Application to Clinical Decision Making, *BRIAN E. FORST, Center for Naval Analyses, University of Rochester, 1401 Wilson Boulevard, Arlington, Virginia 22209.*

WP8.21 Why Not Use BASIC for Operations Research Programming Needs, *C. JOSEPH SASS, Department of Operations Analysis, College of Business Administration, University of Toledo, Toledo, Ohio 43606.*

Annual Business Meeting of the
Operations Research Society of America
5:00–6:00 in Sam Houston Room

THURSDAY AM, MAY 6 **Pioneer Room**

Session: TA1 9:00–12:00
Panel on: Tactical Air Power in the Eighties
(Sponsored by Military Applications Section)

Chairman: GEORGE HAERING
Office of Chief of Naval Operations,
(OP-96),
Pentagon, Room BD 770,
Washington, D.C.

Panel: EDMUND DEWS, *RAND Corporation, 1700 Main Street, Santa Monica, California 90401,* H. M. FISH, *Headquarters, USAF, Air Staff, Pentagon, Room 4D1083, Washington, D.C.,* GEORGE HAERING, R. L. McDANIEL, *Office of Secretary of Defense, Office of Director Defense Research and Engineering, Pentagon, Room 3E1060, Washington, D.C.,* K. P. RICE, *USMC, Naval Weapons Center, China Lake, California 93557,* ALLAN SIMON, *Office of Director Defense Research and Engineering, Department of the Navy, Pentagon Room 3E1047, Washington, D.C.,* and G. H. SMITH, *ODDR&E Pentagon, Room 3E1047, Washington, D.C.*

THURSDAY AM, MAY 6 Sam Houston Room

Session: TA2 9:00–12:00
Progress in the Application of Health Operations Research
(Sponsored by Health Applications Section)

Chairman. JOHN R. HALL
National Center for Health Services
Research and Development, Room 15-22,
Parklawn Building,
5600 Fishers Lane,
Rockville, Maryland 20852

*TA2.1 Evolving Techniques for Health Systems Analysis, *CHARLES D. FLAGLE, The Johns Hopkins University, 615 North Wolfe Street, Baltimore, Maryland 21205.*

*TA2.2 Progress in the Public Support of the Health System Concept, *GILBERT D. BARNHART, National Center for Health Services Research and Development, Health Services and Mental Health Administration, Department of Health, Education and Welfare, 5600 Fishers Lane, Rockville, Maryland 20852.*

*TA2.3 Community Health Care – Problems and Progress, *WILLIAM J. HORVATH, Mental Health Research Institute, University of Michigan, Ann Arbor, Michigan 48104.*

*TA2.4 Progress in the Application of OR/SA to Hospital Services, *JOHN R. GRIFFITH, Bureau of Hospital Administration, University of Michigan, 220 E. Huron, Ann Arbor, Michigan 48108*

THURSDAY AM, MAY 6 Stephen F. Austin Room

Session: TA3 9:00–12:00
Large-Scale Systems

Chairman: LEON S.LASDON
Operations Research Department,
Case Western Reserve University,
Cleveland, Ohio 44106

*TA3.1 A Survey of Large-Scale Mathematical Programming, *LEON S. LASDON, Operations Research Department, Case Western Reserve University, Cleveland, Ohio 44106.*

TA3.2 A Decomposition Algorithm for Finding Shortest Paths in a Special Type of Sparse Network, *JIN Y. YEN, University of Santa Clara, Santa Clara, California 95053.*

*TA3.3 Progress in Large-Scale Optimization, *ARTHUR M. GEOFFRION, Graduate School of Business Administration, University of California, Los Angeles, California 90024.*

*TA3.4 A Primal Method for Linear Programs with Coupling Rows and Columns, *JAMES K. HARTMAN, Department of Operations Analysis, Naval Postgraduate School, Monterey, California 93940.*

*TA3.5 Naive Linear Programming, *JAMES E. KALAN, Computer Science/Operations Research Center, Southern Methodist University, Dallas, Texas 75222.*

*TA3.6 Comments on Dynamic Optimization, *GEORGE B. DANTZIG, Operations Research Department, Stanford University, Stanford, California 94305.*

*TA3.7 An Algorithm for Structural Quadratic Programs, *MICHAEL GRIGORIADIS, IBM Corporation, 112 East Post Road, White Plains, New York 10601.*

THURSDAY AM, MAY 6 W. B. Travis Room

Session: TA4 9:00–12:00
Inventory Theory

Chairman: DONALD L. IGLEHART
Department of Operations Research,
Stanford University,
Stanford, California 94305

*TA4.1 Simple Approximations for Some Constrained Continuous Review Inventory Systems, *EVAN L. PORTEUS, Graduate School of Business, Stanford University, Stanford, California 94305.*

*TA4.2 Minimax Inventory Models, *EDMUND M. NOTZON, III, Office of the Assistant Secretary of Defense for Systems Analysis, The Pentagon, Washington, D.C. 20301*

*TA4.3 A Multi-Facility, Single-Supplier Inventory Problem, *FELIPE K. TAN, Western Electric Engineering Research Center, P.O. Box 900, Princeton, New Jersey 08540.*

TA4.4 Comparison of Alternative Inventory Supply Policies: Multipurpose Vs Special Purpose Equipment, *GARY J. HANDLER, Bell Laboratories, Holmdel, New Jersey 07733.*

TA4.5 Inventory Allocation Among An Assembly and Its Repairable Subassemblies, *EDWARD A. SILVER, Department of Management Sciences, University of Waterloo, Waterloo, Ontario, Canada.*

TA4.6 Optimal Positioning of Inventory Stock in a Multi-Echelon System, *GEORGE F. BROWN, JR., LESTER P. SILVERMAN, RALPH J. VANNI, Center for Naval Analyses, 1401 Wilson Boulevard, Arlington, Virginia 22209.*

TA4.7 Inventory Systems With Imperfect Asset Information, *DONALD L. IGLEHART, Department of Operations Research, Stanford University, Stanford, California 94305, and RICHARD C. MOREY, DECISION Studies Group, 3260 Hillview Avenue, Palo Alto, California 94304*

TA4.8 Optimization of Batch Ordering Under Deterministic Variable Demand, *SALAH E. ELMAGHRABY and VISHWAS Y. BAWLE, Department of Industrial Engineering, North Carolina State University, Box 5511, Raleigh, North Carolina 27607.*

TA4.9 Continuous-Review (s,S) Inventory Models With State-Dependent Leadtime, *DONALD GROSS and CARL M. HARRIS, The George Washington University, School of Engineering and Applied Science, Institute for Management Science and Engineering, Washington, D.C. 20006.*

THURSDAY AM, MAY 6 **Vaquero Room**

Session: TA5 9:00–12:00
Air Traffic Control
(Sponsored by: Transportation Science Section)

Chairman: ROBERT W. SIMPSON
Department of Aeronautics and Astronautics,
Massachusetts Institute of Technology, Cambridge, Massachusetts 02139

***TA5.1** Modelling for Air Traffic Control Systems, *AMEDEO R. ODONI, Room 9-236, CAES, Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge, Massachusetts 02139.*

***TA5.2** Air Terminal Queues under Time-Dependent Conditions, *B. O. KOOPMAN, Arthur D. Little, Inc., Acorn Park, Cambridge, Massachusetts 02140.*

***TA5.3** Analysis of Pilot Warning Indicator Performance Using Digital Computer Fast-Time Simulation, *J. RAY RUETENIK, Aerodynamics Section, Kaman Avidyne Division, Kaman Sciences Corporation, Burlington, Massachusetts 01803; WILLIAM R. LANGE, American Airlines, Inc., Corporate Planning, New York, New York, and JOHN H. THOMPSON, Kaman Avidyne Division, Kaman Sciences Corporation, Burlington, Massachusetts 01803.*

TA5.4 Optimal Self-Perpetuating Flow in a Closed-Loop Air Traffic Control Network, *JAMES W. EYSTER, Department of Industrial Engineering, The Ohio State University, Columbus, Ohio 43210.*

THURSDAY AM, MAY 6 Alamo Room

Session: TA6 9:00–12:00
Recent Research and Developments in Budgeting Theory and Practice

Chairmen: A. CHARNES
School of Business Administration, University of Texas at Austin, Austin, Texas 78712
and
W. W. COOPER
School of Urban and Public Affairs, Carnegie-Mellon University, Pittsburgh, Pennsylvania 15213

This covers a forthcoming second volume, STUDIES IN BUDGETING, which is to accompany the 1969 TIMS–ONR Award volume, THE EVALUATION OF RISKY INTERRELATED INVESTMENTS. Reprints of STUDIES IN BUDGETING will be available at this session.

***TA6.1** Recent Research and New Developments in Budgeting Theory and Practice–A Survey and Evaluation, *ROBERT F. BYRNE, University of Pittsburgh, Pittsburgh, Pennsylvania.*

***TA6.2** A Basic Approach to the Evaluation of Risky Interrelated Investments, *FREDERICK S. HILLIER, Stanford University, Operations Research Department, Stanford, California 94305.*

***TA6.3** CC and LPUU Combinations for Treating Different Risks and Uncertainties in Capital Budgets, *ROBERT F. BYRNE, University of Pittsburgh, Pittsburgh, Pennsylvania; A. CHARNES, School of Business Administration, University of Texas at Austin, Austin, Texas 78712; W. W. COOPER and K. O. KORTANEK, School of Urban and Public Affairs, Carnegie-Mellon University, Pittsburgh, Pennsylvania 15213.*

***TA6.4** A Model of Capital Budgeting Under Risk, *BERTIL NASLUND, Stockholm University, Department of Business Administration, Fack 10405, Stockholm 50, Sweden.*

***TA6.5** Some New Views on the Payback Period and Capital Budgeting Decisions, *H. MARTIN WEINGARTNER, The Graduate School of Management, The University of Rochester, Rochester, New York 14627.*

***TA6.6** PPBS – An Analytical Approach, *TIMOTHY W. RUEFLI, University of Texas at Austin, Graduate School of Business, B.E.B. 517, Austin, Texas 78712.*

***TA6.7** Defense Budgeting: Organizational Adaptation to Environmental Constraints, JOHN P. CRECINE, University of Michigan, Institute of Public Policy, Ann Arbor, Michigan.

***TA6.8** Towards a Theory of Public Budgetary Decision Making, *DONALD GERWIN, School of Business Administration, University of Wisconsin, Milwaukee, Wisconsin.*

***TA6.9** The Process of Budgeting II. An Empirical Study of Congressional Appropriations, *O. A. DAVIS, Carnegie-Mellon University, Pittsburgh, Pennsylvania 15213; M. A. H. DEMPSTER, Balliol College, Oxford, England, and A. WILDAVSKY, University of California, Berkeley, California 94720.*

THURSDAY AM, MAY 6 Ballroom Foyer

Session: TA7 9:00–10:15
Simultaneous Session V

Chairman: V. J. BOWMAN
Graduate School of Industrial Administration, Carnegie-Mellon University, Pittsburgh, Pennsylvania 15213

TA7.1 Some Discrete-time Models with Linear Transition Rate, *HERMAN STEIN, School of Business, State University of New York, 1400 Washington Avenue, Albany, New York 12203.*

TA7.2 The Effect that the Probability of a Successful Approach Has on the Sequential Landing Rate of Like Aircraft, *EDWIN M. GOLDBERG, Concord Research Corporation, 12 New England Executive Park, Burlington, Massachusetts 01803.*

TA7.3 Location of Inspection Stations in an Assembly Line by Integer Programming, *LLOYD A. SWANSON and DONALD J. AGOSTINO, College of Business Administration, Syracuse University, Syracuse, New York 13210.*

TA7.4 Funds Allocation Model, *WALTER L. DE VRIES, Equitable Life Assurance Society, 1285 Avenue of the Americas, New York, New York 10019.*

TA7.5 COBRA/TANK Assessment Model, *C. E. MANLEY and W. F. FULKERSON, P. O. Box 269, Leavenworth, Kansas 66048.*

TA7.6 Optimal Strategy for the Expansion of Airport Terminals: A Cost-Effectiveness Analysis, *RICHARD DE NEUFVILLE, Massachusetts Institute of Technology, Civil Engineering Systems Laboratory, Cambridge, Massachusetts 02139.*

TA7.7 Selection of Experts, *HARRY E. EMLET, JR., JOHN L. DAVIS, and IRVING J. CASEY, Analytic Services, Inc., 5613 Leesburg Pike, Falls Church, Virginia 22041.*

TA7.8 A Validated Model for the Allocation of Nursing Personnel in an Extended Care Facility, *JUDITH S. LIEBMAN, JOHN P. YOUNG, and MANDELL BELLMORE, The Johns Hopkins University, 615 North Wolfe Street, Baltimore, Maryland 21205.*

TA7.9 Modeling of a Class of Finite Queuing or Repairman Problems with GERT, *MICHAEL H. BRANSON and BHARAT SHAH, Department of Industrial Engineering, University of Rhode Island, Kingston, Rhode Island 02881.*

TA7.10 Nonserial Dynamic Programming: Multilevel Procedures, *UMBERTO BERTELÉ and FRANCESCO BRIOSCHI, Istituto di Elettrotecnica ed Elettronica, Politecnico di Milano, Piazza L. da Vinci, 32–20133 Milano, Milano, Italy.*

TA7.11 Operational Inventory Control with Seasonal Demand, *REIN PETERSON, Faculty of Administrative Studies, York University, Toronto, Canada, and JOSEPH THOMAS, Graduate School of Business and Public Administration, Cornell University, Ithaca, New York 14850.*

TA7.12 A Convex Programming Algorithm, *R. JAGANNATHAN, Division of Operations Research, Columbia University, New York, New York 10027.*

TA7.13 On Multicommodity Maximal Dynamic Flows, *MANDELL BELLMORE and RAMAKRISHNA R. VEMUGANTI, The Johns Hopkins University, Department of Operations Research, Baltimore, Maryland 21218.*

TA7.14 Computational Experience with Applications of State Increment Dynamic Programming to Industrial Management Problems, *R. N. KAPUR, IBM Components Division, East Fishkill Facility, Hopewell Junction, New York 12533.*

(Continued)

TA7.15 Optimal Control of Research and Development Expenditures, *CARL W. HAMILTON, Graduate School of Business Administration, University of Southern California, Los Angeles, California 90007.*

TA7.16 A Mathematical Programming Approach to the Cost Effectiveness Analysis of a Family of Military Engineering Construction Equipment, *WILLIAM G. SCOTT, Peat, Marwick, Mitchell and Company, 1025 Connecticut Avenue, Washington, D.C. 20036.*

TA7.17 A Schematic Schedule of Program Plan, *YING C. CHUANG, Center for Urban Education, 105 Madison Avenue, New York, New York 10016.*

TA7.18 The Economics of Group Practice in Medicine, *WILLIAM LAWRENCE, Hofstra University, Hempstead, New York.*

TA7.19 Public Sector Routing Models, *ROBERT STRICKER, Bell Laboratories, Holmdel, New Jersey, and DAVID H. MARKS, Department of Civil Engineering, Room 1-274, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139.*

TA7.20 A Square Root Law for Fire Engine Effectiveness, *PETER J. KOLESAR, Université de Montréal, Case Postale 6128, Montréal 101, Canada.*

TA7.21 Controllability and Observability in Dynamic Operations Research Models, *B. L. CAPEHART, Industrial and Systems Engineering, University of Florida – Genesys, 7300 Lake Ellenor Drive, Orlando, Florida 32809, and R. B. WADSWORTH, Industrial Engineering, Texas A&M University, College Station, Texas 77843.*

THURSDAY, AM MAY 6 **Ballroom Foyer**

Session: TA8 10:30–11:45
Simultaneous Session VI

Chairman V. J. BOWMAN
Graduate School of Industrial Administration, Carnegie-Mellon University, Pittsburgh, Pennsylvania 15213

TA8.1 A Markovian Analysis of Performer-Oriented Systems, *RONALD LESSING, Social Security Administration, Department of Health, Education, and Welfare, 3316 Lynne Haven Drive, Baltimore, Maryland 21207, and WILLIAM B. WIDHELM, Department of Business and Public Administration, University of Maryland, College Park, Maryland 20742.*

TA8.2 Grade Acceptance Simulation Model, *E.B. COHEN, S. L. KOHR and D. J. LOUICK, Atlantic Richfield Company, 260 South Broad Street, Philadelphia, Pennsylvania 19101.*

TA8.3 A Determination of Resource Requirements for an ASW Mission, *J. A. WHITE and K. E. CASE, Department of Industrial Engineering and Operations Research, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061.*

TA8.4 A Study of Patient Load Patterns in a Community Hospital, *GERALD R. ADLER, I.B.M., Endicott, New York, and AMRIT L. GOEL, Department of Industrial Engineering, Syracuse University, Syracuse, New York 13210.*

TA8.5 A Bayesian Approach to Determining the Sample Size for Testing of AF Weapons Systems, *KENNETH E. BRANT, Air Force Institute of Technology, Wright-Patterson AFB, Ohio, and PAUL BRITT, Hq USAF, ZSDZ, The Arms Control and Disarmament Agency, Weapons Evaluation & Con-*

trol Bureau, Operations Analysis Division, New State Department Building, Washington, D.C. 20451.

TA8.6 Systems Requirements for Operational Gaming, *S. M. LINDSAY, J. C. ROBINSON, and J. A. BATTILEGA, US Army Strategy and Tactics Analysis Group, 8120 Woodmont Avenue, Bethesda, Maryland 20014.*

TA8.7 A Program for the Allocation of Government Expenditures to Stabilize National Income, *SEDAT SAMI ERCAN, Roosevelt University, 430 South Michigan Avenue, Chicago, Illinois 60605.*

TA8.8 Predicting Information Costs in a Management Information System, *ROBERT T. RILEY and THOMAS A. WILLIAMS, Department of Quantitative Analysis, University of Cincinnati, Cincinnati, Ohio 45221.*

TA8.9 Casino Solo. Dynamic Extraction of a Monotonic Sequence from a Random Process, *DAVID W. MATULA, Department of Applied Mathematics and Computer Science, Washington University, St. Louis, Missouri 63130.*

TA8.10 Stochastic Design Models for Location and Allocation of Service Facilities on a Network, *SHALER STIDHAM, JR., Department of Operations Research, Cornell University, Ithaca, New York 14850.*

TA8.11 Modeling of a Satellite Airport System for Large Metropolitan Areas, *INDER K. SUD and PAUL GRAY, Industrial Engineering Department, Stanford University, Stanford, California 94305.*

TA8.12 Duality in the Transportation Model–II, *V. SRINIVASAN and G. L. THOMPSON, Graduate School of Industrial Administration, Carnegie-Mellon University, Pittsburgh, Pennsylvania 15213.*

TA8.13 Kalman Filtering Applications in Economic and Inventory Systems, *B. L. CAPEHART, Industrial and Systems Engineering Department, University of Florida/GENESYS, Orlando, Florida 32809, and C. S. BAUER, Industrial Engineering and Management Systems Department, Florida Technological University, Orlando, Florida.*

TA8.14 Simultaneous Decision Making Among Functional Areas of the Firm, *WILLIAM W. DAMON, Graduate School of Business Administration, Duke University, Durham, North Carolina 27706.*

TA8.15 An Evaluation of the Effectiveness of Mathematical Programming Models for R & D Project Selection, *WILLIAM E. SOUDER, Department of Industrial Engineering and Management Sciences, The Technological Institute, Northwestern University, Evanston, Illinois 60201.*

TA8.16 Optimization of In-Process Test Limits, *HARLEY L. LYONS, Department 517, Systems Manufacturing Division, IBM Corporation, Box 1900, Boulder, Colorado 80302.*

TA8.17 Stochastic Multicommodity Network Flow, *M. BELLMORE, The Johns Hopkins University, Baltimore, Maryland 21218, and J. W. CRAWFORD, Bell Telephone Laboratories, Inc., Whippany, New Jersey 07981.*

TA8.18 Models for the Allocation of Vehicles to Parking Lots at an Urban Campus, *R. GRAHAM J. MILLS, Department of Industrial Engineering and Operations Research, Wayne State University, Detroit, Michigan 48202.*

TA8.19 Robustness of Tandem Queueing Models, *HENRY D. FRIEDMAN, 570 Torwood Lane, Los Altos, California 94022, and GENO TOLARI, Informatics Incorporated, Palo Alto, California 94303.*

TA8.20 Operations Research and the Administration of Justice, *THOMAS L. MORIN, Department of Industrial Engineering and Management Sciences, Northwestern University, Evanston, Illinois 60201.*

THURSDAY PM, MAY 6 **Sam Houston Room**

Distinguished Lecture II 1:00–1:50

THOMAS L. SAATY
Wharton School of Finance and Commerce, Management Science Center, University of Pennsylvania, Philadelphia, Pennsylvania 19104

The Present Status and Future Growth and Needs of Operations Research in the Government

The three levels of O.R. practice in government are 1) the operating tactical level closely associated with performance; 2) the intermediate advisory and consulting level associated with small scale strategy; and 3) the high, strategic level involving design and implementation of national policy.

At the first two lower levels O.R. has done reasonably well. Because of its complex political ramifications, the third level has used presidential appointees from all walks of life. Thus, O.R. people may have participated but rarely been leaders. Policy recommendations also come as a result of congressional interest or fact-finding studies outside the government.

Policies at the highest level should derive from a good understanding of national objectives. But even the development of national objectives requires planning which has not been done in an integrated way, resulting in suboptimization with one department hurting the interests of another. Perhaps the process of implementation is even more important than planning. The best plan can fail in the hands of a poorly designed organization. Traditionally, people have felt that given a good plan almost any organization can put it into effect. Experience has shown otherwise. Operations Research needs to say more about this area for the government as it has successfully done for business. In this sense, the future prospects of Operations Research in the government are very much brighter and more inviting than its course has been so far.

O.R. practices can be most effective if O.R. practitioners work at the presidential or congressional advisory level and to a lesser extent by having individuals as members on panels and other independent studies.

One of the major factors which can diminish the effectiveness of O.R. planning is the role of politics and lobbies. It takes so long to do so little by so many. To that end, O.R. may need to say something about politics and about effective organizations that are not impaired by changing political winds. We must either do that, or continue to practice O.R. at such low levels that the major problems of society remain essentially untouched by the broader, less compartmented view of Operations Research.

What is needed today are illustrative studies of what can be done to show that we have something specific to offer. Studies in national solid waste disposal problems, ghettos, and in international conflict problems are examples on which progress has been made.

THURSDAY PM, MAY 6 **Pioneer Room**

Session: TP1 2:00–5:00
Panel on: Relevancy of Operations Research

Chairman: RICHARD V. EVANS
College of Commerce and Business Administration, University of Illinois, Urbana, Illinois 61801

Panel: THOMAS E. CAYWOOD, *Caywood-Schiller and Associates, 401 North Michigan Avenue, Chicago, Illinois 60611,* RICHARD V. EVANS; DONALD L. IGLEHART, *Operations Research Department, Stanford University, Stanford, California 94305,* KENNETH O. KORTANEK, *School of Urban and Public Affairs, Carnegie-Mellon University, Pittsburgh, Pennsylvania 15213,* HUGH J. MISER, *Box 525, Windsor, Connecticut 06095,* ROBERT M. THRALL, *Department of Mathematical Sciences, Rice University, Houston, Texas 77001.*

Is OR working on the most meaningful problems? Is the problem mix reacting to society's changing needs? Has appropriate professionalism developed? Has theory failed to react to changing interests? Has theory become an empty academic exercise? These are some of the questions which can be raised in considering the relevancy of OR. This session is intended to provide an informal forum for discussion of these questions. Time will be reserved for members of the audience to join in the discussions of the panel.

THURSDAY PM, May 6 **Sam Houston Room**

Session: TP2 2:00–5:00
Urban Problems I

Chairman. ALFRED BLUMSTEIN
Urban Systems Institute, Carnegie-Mellon University, Pittsburgh, Pennsylvania 15213

***TP2.1** Operational Research in English Urban Problems, *PETER THURSFIELD, Local Government Operational Research Unit, 201 King's Road, Reading RG 1 4LH, England.*

***TP2.2** Urban Fire Protection Analyses of Operations in the New York City Fire Department, *EDWARD H. BLUM, New York City RAND Institute, 545 Madison Avenue, New York, New York 10022.*

***TP2.3** Planning the Criminal Detection Activities of the Police, *VINCENT C. WATTS, Arthur Andersen and Company, St. Alphage House, 2 Fore Street, London E. C. 2., England.*

***TP2.4** A Case Study in Manpower Scheduling, *LAWRENCE D. BODIN, ALLAN TUCKER, EDWARD J. BELTRAMI, and STANLEY M. ALTMAN, State University of New York, Stony Brook, New York 11790.*

***TP2.5** Discussant: *E.S SAVAS, First Deputy City Administrator, City of New York, New York.*

THURSDAY PM MAY 6 **Stephen F. Austin Room**

Session: TP 3 2:00–5:00
Research and Development

Chairman: ALBERT SHAPERO
School of Business Administration, University of Texas at Austin, Austin, Texas 78712

*TP3.1 *ALBERT SHAPERO, School of Business Administration, University of Texas at Austin, Austin, Texas 78712.*

*TP3.2 *NORMAN WAKS, MITRE Corporation, 1820 Dolly Madison Boulevard, McLean, Virginia 22101.*

*TP3.3 *ROBERT HEMMES, Department of Transportation, Washington, D.C.*

*TP3.4 *SAADIA M. SHORR, General Electric Center for Advanced Studies, Santa Barbara, California.*

The session will lead off with a review of applications of operations research to research and development. Following the review will be three talks given by men who are not only outstanding operations research practitioners, but also managers of research and development projects and funds. They will discuss the various aspects of applications and the relevance of operations research to the management of research and development.

THURSDAY PM, May 6 **W. B. Travis Room**

Session: TP4 2:00–5:00
Networks and Graphs I

Chairman JACK EDMONDS
Department of Combinatorics and Optimization, University of Waterloo, Waterloo, Ontario, Canada

*TP4.1 A Survey of Practical Applications of Network Analysis, *DANIEL J. KLEITMAN, Department of Mathematics, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139.*

*TP4.2 Maximally Connected Subgraphs of a Graph, *DAVID W. MATULA, Department of Applied Mathematics and Computer Science, Washington University, St. Louis, Missouri 63130.*

*TP4.3 Equitable Colorations of a Graph and a Type of Scheduling Problem, *D. DE WERRA, Department of Management Science, University of Waterloo, Ontario, Canada.*

*TP4.4 All Shortest Distances in Large Serial Networks, *JOHN M. BURT, JR., Graduate School of Business Administration, University of California, Los Angeles, California 90024.*

TP4.5 On the Efficiencies of Algorithms for Detecting Negative Loops in Networks, *JIN Y. YEN, University of Santa Clara, Santa Clara, California 95053.*

TP4.6 A New Method for Cost-Duration Analysis in Project Networks, *E. J. DUNNE and M. I. DESSOUKY, Department of Mechanical and Industrial Engineering, University of Illinois, Urbana, Illinois 61801.*

THURSDAY PM, MAY 6 Vaquero Room

Session: TP5 2:00–5:00
Operations Research and Statistics

Chairman: JOHN E. WALSH
Statistics Department, Southern Methodist University, Dallas, Texas 75222

*TP5.1 A Statistical Analysis of Traffic Control Strategies, *PREM K. MUNJAL, System Development Corporation, Santa Monica, California 90406*

*TP5.2 On Selecting Statistical Data Analysis Techniques for Space Station Applications, *PATRICK L. ODELL, Department of Mathematics, Texas Tech University, Lubbock, Texas 79409.*

*TP5.3 An Information-Theoretic Approach to Stimulus Sampling: A Cross-Cultural Analysis, *JEROME B. KERNAN, University of Cincinnati, Cincinnati, Ohio and LAWRENCE L. SCHKADE, University of Texas, Arlington, Texas 76010.*

TP5.4 An Empirical Bayes Estimator for the Scale Parameter of the Two-Parameter Weibull Distribution, *G. KEMBLE BENNETT, Department of Industrial Engineering and Operations Research, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061.*

TP5.5 Bayesian Sequential Multi-Decision Data Collection, *NORMAN H. NOE, Bell Laboratories, Holmdel, New Jersey 07733, and S. EHRENFELD, New York University, New York, New York.*

THURSDAY PM, MAY 6 Alamo Room

Session: TP6 2:00–5:00
Operations Research in Ecology and Biology

Chairman: STUART H. MANN
Division of Man-Environment Relations, Pennsylvania State University, University Park, Pennsylvania 16802

*TP6.1 Managing the Environment, *WALTER R. LYNN, School of Civil and Environmental Engineering and Center for Environmental Quality Management, Cornell University, Ithaca, New York 14850.*

*TP6.2 Mathematical Models for the Control of Growing Biological Populations: *A Survey, DAVID L. JAQUETTE, Department of Industrial and Systems Engineering, University of Southern California, Los Angeles, California 90007.*

*TP6.3 A Survey of Mathematical Application to Water Pollution Control, *ANDREW WHINSTON, Krannert Graduate School of Industrial Administration, Purdue University, Lafayette, Indiana 47907, and GLENN GRAVES, Graduate School of Business, University of California, Los Angeles, California 90024.*

*TP6.4 Ecological Simulations: Biospheric Operations Research and the Carbon Cycle, *JERRY S. OLSON, Botany Department, University of Tennessee, Knoxville, Tennessee 37916.* ,

*TP6.5 A System for the Stochastic Simulation of Even-Aged Forest Stands of Pure Species Composition, *PETER E. DRESS, School of Forest Resources, Pennsylvania State University, University Park, Pennsylvania 16802.*

THURSDAY PM, MAY 6 Ballroom Foyer

Session: TP7 2:00–3:15
Simultaneous Session VII

Chairman: HAMILTON EMMONS
Department of Operations Research, Cornell University, Ithaca, New York 14850

TP7.1 Projection of Student Enrollment by a Two-Step Markovian Process, *WARREN R. HARDEN and MIKE T. TCHENG, Academic Planning and Institutional Research, Illinois State University, Normal, Illinois 61761.*

TP7.2 Risk Simulation for a Proposed Plant Location, *THOMAS L. HONEYCUTT, Computer Science Department, North Carolina State University, Raleigh, North Carolina.*

TP7.3 A Cost-Effectiveness Approach to Staff Assignment, *YING C. CHUANG, Center for Urban Education, 105 Madison Avenue, New York, New York 10016, and FUN KUN TSAI, National Ching Chu University, Taipei, Taiwan, Republic of China.*

TP7.4 The U. S. Naval Weapons Laboratory Minehunting Model, *JOHN L. BAILEY, U. S. Naval Weapons Laboratory, Dahlgren, Virginia 22448.*

TP7.5 The Dynamic Assessment of Risk, *MICHAEL A. LEONE, Systems Analysis, Hughes Tool Company, Aircraft Division, Culver City, California.*

TP7.6 Dynamic Optimization of Pollutants of Multiproducts of Multifirms, *S. BASHEER AHMED, Department of Business Administration, Western Kentucky University, Bowling Green, Kentucky 42101.*

TP7.7 Use of Simulation and Optimization in Texas Water Planning, *W. L. MEIER, JR., Department of Industrial Engineering, Texas A & M University, College Station, Texas 77843, and ARDEN O. WEISS, Systems Engineering Division, Texas Water Development Board, Austin, Texas 78711.*

TP7.8 Cost, Effectiveness and Patient Care, *DANIEL HOWLAND, College of Administrative Science, The Ohio State University, Columbus, Ohio 43210.*

TP7.9 A Multi-Channel Communication System, *PAUL R. MILCH, Department of Operations Analysis, Naval Postgraduate School, Monterey, California 93940.*

TP7.10 Highway and Transit Capacity Additions to Urban Transportation Networks, *OMER SAATÇİOĞLU, Industrial Engineering Department, M.E.T.U., Ankara, Turkey, ALBERT G. HOLZMAN, Industrial Engineering Department, University of Pittsburgh, Pittsburgh, Pennsylvania, and WILLIAM L. GARRISON, Civil Engineering Department, University of Pittsburgh, Pittsburgh, Pennsylvania.*

TP7.11 Minimum Cost Equipment Selection for Distribution Warehouses, *PAUL S. JONES, Stanford Research Institute, Menlo Park, California 94025.*

TP7.12 Manpower Scheduling Decision Rules for A Single Post Office, *L. J. KRAJEWSKI and L. P. RITZMAN, 1775 South College Road, The Ohio State University, Columbus, Ohio 43210.*

TP7.13 The Minimum Covering Sphere Problem, *D. JACK ELZINGA and DONALD W. HEARN, Department of Operations Research and Industrial Engineering, The Johns Hopkins University, Baltimore, Maryland 21218.*

TP7.14 Optimal Strategies for Capacity Expansion, *AVADHESH K. NIGAM, Operations Research, RCA Corporation, Princeton, New Jersey 08540.*

TP7.15 Analysis of Production and Inventory Systems with Stochastic Behavior, *JON T. MILLER, USAMC Intern Training Center, Red River Army Depot, Texarkana, Texas 75501.*

TP7.16 A Multi-Objective Scheduling Problem with Uncertain Demand, *DAVID SAVIR, IBM Corporation, Armonk, New York 10504.*

TP7.17 A Scheduling Procedure to Optimize a Dynamic Natural Energy System, *RICHARD D. HAYNES, U. S. Bureau of Mines and West Virginia University, Department of Industrial Engineering, Morgantown, West Virginia 26505, JACK BYRD, JR., U. S. Bureau of Mines and West Virginia University, Department of Industrial Engineering, Morgantown, West Virginia 26505, and LEO A. SCHRIDER, U. S. Bureau of Mines, Morgantown, West Virginia 26505.*

TP7.18 Interpretation of the Air Traffic Control Beacon System Operation as a Queueing Process with Zero Length Queue, *EDWIN M. GOLDBERG, Concord Research Corporation, 12 New England Executive Park, Burlington, Massachusetts 01803.*

THURSDAY PM, MAY 6 Ballroom Foyer

Session: TP8 3:30–4:45
Simultaneous Session VIII

Chairman: HAMILTON EMMONS
Department of Operations Research, Cornell University, Ithaca, New York 14850.

TP8.1 A Dynamic Programming Approach to Competitive Alternate Bidding, *MICHAEL DEVINE and HILLEL KUMIN, School of Industrial Engineering, The University of Oklahoma, Norman, Oklahoma 73069.*

TP8.2 Can Educational Achievement Be Predicted?, *ROBERT GRAUER, Graduate School of Management Engineering, C. W. Post College, Greenvale, New York 11548, and STUART DEUTSCH, Department of Operations Research and Systems Analysis, Polytechnic Institute of Brooklyn, 333 Jay Street, Brooklyn, New York 11201.*

TP8.3 Mathematical Model Design and Reliability Analysis of a Weapon Control System, *RUDOLF ALLAN BULMANN and CHARLES R. WHITE, Industrial Engineering Department, Auburn University, Auburn, Alabama 36830.*

TP8.4 Technological Assessment: Societal And Environmental Parameters, *J. N. FOX, Department of Industrial Engineering, The University of Texas at Arlington, Arlington, Texas.*

TP8.5 Optimal Issuing Policies for a Perishable Inventory under Stochastic Demand and Uncertain Consumption, *WILLIAM P. PIERSKALLA, Department of Industrial Engineering, Northwestern University, Evanston, Illinois 60201.*

TP8.6 An Algorithm for the Plant Location Problem, *R. L. BULFIN and V. E. UNGER, Department of Industrial and Systems Engineering, Georgia Institute of Technology, Atlanta, Georgia 30332.*

TP8.7 The Bottleneck Transportation Problem, *R. S. GARFINKEL and M. R. RAO, Graduate School of Management, University of Rochester, Rochester, New York 14627.*

TP8.8 Characteristics of Constant-Speed Recirculating Conveyors with Markovian Loadings and Services, *LYNN E. BUSSEY, Department of Industrial Engineering, Kansas State University, Manhattan, Kansas, and M. PALMER TERRELL, School of Industrial Engineering and Management, Oklahoma State University, Stillwater, Oklahoma 74074.*

TP8.9 Applications of Mathematical Programming to Computer Science, *ALAN C. WHEELER, Computer Science/Operations Research Center, Southern Methodist University, Dallas, Texas 75222.*

TP8.10 Computational Aspects of the Multi-Commodity Production Planning Problem, *PAUL R. KLEINDORFER, Massachusetts Institute of Technology, Alfred P. Sloan School Of Management, 50 Memorial Drive, Cambridge, Massachusetts 02139.*

TP8.11 Alternatives to Dynamic Programming for Dynamic Lotsizes, *ADOLF DIEGEL, University of South Alabama, Mobile, Alabama 36608.*

TP8.12 Maximal Funnel-Node Flow in an Undirected Network, *DUANE D. MILLER, Office of the Assistant Vice Chief of Staff, U. S. Army, The Pentagon, Washington, D.C. 20310, and JOHN J. JARVIS, School of Industrial Engineering, Georgia Institute of Technology, Atlanta, Georgia.*

TP8.13 Geometric Programming via a Primal Auxiliary Problem, *G. V. REKLAITIS, School of Chemical Engineering, Purdue University, Lafayette, Indiana 47907, and D. J. WILDE, Department of Chemical Engineering, Stanford University, Stanford, California 94305.*

TP8.14 Cost-Benefit Study of Computerized Regional Blood Inventory System, *K. KENDALL, C. C. PEGELS and J. P. SEAGLE, School of Management, State University of New York at Buffalo, Main Street, Buffalo, New York 14214.*

TP8.15 Cost Sensitivity Analysis for a Radiology Planning Problem, *G. J. THUESEN, School of Industrial and Systems Engineering, Georgia Institute of Technology, Atlanta, Georgia 30332, and W. G. SULLIVAN, Division of Health Systems Engineering, Medical College of Georgia, Augusta, Georgia 30902.*

TP8.16 Potential Indicators of Efficiency and Effectiveness for The Susquehanna River Basin Plan in Pennsylvania, *CHARLES G. JACKSON, Political Science Department, Bloomsburg State College, Bloomsburg, Pennsylvania 17815.*

TP8.17 Simulating Forest Fire and Its Control, *JAMES B. DAVIS, Pacific Southwest Forest and Range Experiment Station, Forest Fire Laboratory, P.O. Box 5007, Riverside, California 92507.*

TP8.18 Closed-Cycle Urban Waste Treatment Systems, *D. B. DAHM, Cornell Aeronautical Laboratory, Inc., P.O. Box 235, Buffalo, New York 14221.*

TP8.19 Evaluation of Data Bases, *EDWARD T. O'NEILL, School of Information and Library Studies, State University of New York at Buffalo, Buffalo, New York 14214.*

TP8.20 R & D of a Dynamic, Urban, Information System, *ROBERT E. SHANNON, RICHARD M. WYSKIDA, and JAMES P. IGNIZIO, Department of Industrial and Systems Engineering, The University of Alabama in Huntsville, P.O. Box 1247, Huntsville, Alabama 35807.*

FRIDAY AM, MAY 7 **Pioneer Room**

Session: FA1 9:00–12:00
Networks and Graphs II

Chairman: JACK EDMONDS
Department of Combinatorics and Optimization, University of Waterloo, Waterloo, Ontario, Canada

***FA1.1** Flow-Augmenting Meshings and the Maximal Multi-Commodity Flow Problem, *M. BELLMORE and J. P. NETTER, The Johns Hopkins University, Department of Operations Research, Baltimore, Maryland.*

***FA1.2** Multi-Stage, Multi-Commodity Network Flows, *WILLIAM T. TORRES, Department of Mathematics, Wayne State University, Detroit, Michigan 48202.*

FA1.3 Maximal Flow with Gains Through a Special Network, *JOHN J. JARVIS, School of Industrial and Systems Engineering, Georgia Institute of Technology, Atlanta, Georgia, and ANTHONY M. JEZIOR, 107 South Oak Street, Falls Church, Virginia 22046.*

FA1.4 Algorithm for Bounds on Maximal Dynamic Flows, *WILLIAM L. WILKINSON, The George Washington University, 707 22nd Street, N.W., Washington, D.C. 20037.*

***FA1.5** Euler Tours, Matchings, and Chinese Postmen, *ELLIS L. JOHNSON, Thomas J. Watson Research Center, Yorktown Heights, New York 10598.*

***FA1.6** Optimum Branching Systems, *JACK EDMONDS, Department of Combinatorics and Optimization, University of Waterloo, Waterloo, Ontario, Canada.*

FRIDAY AM, MAY 7 **Sam Houston Room**

Session: FA2 9:00–12:00
Urban Problems II

Chairman: WILLIAM D. BRINCKLOE
University Science Center, 3113-3125 Forbes Avenue, Pittsburgh, Pennsylvania 15213

***FA2.1** Progress and Problems in the Urban Environment, *ROBERT PORTER, Environmental Health Agency, Room 1874, Parklawn Building, 5600 Fishers Lane, Rockville, Maryland 20852.*

***FA2.2** A Comprehensive Approach to Urban Growth and Change, *LEO MOLINARO, American City Corporation, Two Wincopin Circle, Columbia, Maryland 21043.*

***FA2.3** A Regional Air Pollution Analysis Model, *ROBERT M. JIMESON, Federal Power Commission, 441 G Street N.W., Washington, D.C. 20426.*

***FA2.4** The Environmental Crisis in Power Generation and Possible Future Directions, *PETER E. GLASER, Arthur D. Little, Inc., Acorn Park, Cambridge, Massachusetts.*

FA2.5 An Operational Residential Growth Model Developed for and Applied to The South Bend, Indiana, Urban Area, *JOSEPH W. GUYTON, REZA M. SAFAVIAN and RONALD D. SCHMIED, Harland Bartholomew and Associates, 188 Jefferson Avenue, Memphis, Tennessee 38103.*

FA2.6 An Environmental Screening Model for the Location of Power Generating Facilities, *DAVID H. MARKS and GERHARD JIRKA, Department of Civil Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139.*

FA2.7 What We Should All Know about the Airport Noise Problem, *INDER K. SUD, Industrial Engineering Department, Stanford University, Stanford, California 94305.*

FRIDAY AM, MAY 7 **Stephen F. Austin Room**

Session: FA3 9:00–12:00
Programming Applications

Chairman: ARTHUR M. GEOFFRION
Graduate School of Business Administration, University of California, Los Angeles, California 90024

***FA3.1** Mathematical Programming Applications to the P's, *M. L. BALINSKI, Graduate Studies Division, City University of New York, 33 West 42 Street, New York, New York, and R. H. COBB, Mathematica, P.O. Box 92, Princeton, New Jersey 08540.*

***FA3.2** Sensitivity Analysis in Chemical Thermodynamics, *J. H. BIGELOW and N. Z. SHAPIRO, The RAND Corporation, Santa Monica, California.*

***FA3.3** Vehicle Loading, *GLENN W. GRAVES, Graduate School of Business Administration, University of California, Los Angeles, California 90024.*

***FA3.4** A Candle to Saint Jude, or Three Real World Applications of Integer Programming, *GENE WOOLSEY, Institute for Operations Research, Colorado School of Mines, Golden, Colorado.*

FA3.5 Optimal Plant Location with Concave Costs, *RICHARD M. SOLAND, Research Analysis Corporation, McLean, Virginia 22101.*

FRIDAY AM, MAY 7 W. B. Travis Room

Session: FA4 9:00–12:00
Simulation

Chairman: DONALD P. GAVER
Department of Statistics Carnegie-Mellon University,
Pittsburgh, Pennsylvania 15213

*FA4.1 Managing the Development of a Simulation Model, *W. EARL SASSER and R. P. OLSEN, Harvard University, Graduate School of Business Administration, Soldiers Field, Boston, Massachusetts 02163.*

*FA4.2 Statistical Estimation of Large Numbers of Percentiles in Simulations, *P. A. W. LEWIS and A. S. GOODMAN, IBM Thomas J. Watson Research Center, Yorktown Heights, New York.*

FA4.3 Application of a GERT Simulator to a Repetitive Hardware Development Type Project, *JOSEPH J. MODER, RICHARD A. CLARK and RAMON S. GOMEZ, Department of Industrial Engineering and Systems Analysis, University of Miami, Coral Gables, Florida.*

*FA4.4 Generating Telephone Traffic-Capacity Tables by Simulation, *M. M. BUCHNER, JR., and R. V. LANE, Bell Telephone Laboratories, Inc., Holmdel, New Jersey.*

*FA4.5 Estimating Connectivity in Probabilistic Networks, *H. FRANK, Network Analysis Corporation, Beechwood, Old Tappan Road, Glen Cove, New York 11542.*

FRIDAY AM, MAY 7 Vaquero Room

Session: FA5 9:00–12:00
Reliability and Maintainability

Chairman: FRANK PROSCHAN
Department of Statistics,
Florida State University,
Tallahassee, Florida 32306

*FA5.1 A Problem in Accelerated Life Testing, *NOZER D. SINGPURWALLA, Institute for Management Science and Engineering, George Washington University, Washington, D.C.*

*FA5.2 Conservative Availability Prediction, *J. D. ESARY, Naval Postgraduate School, Monterey, California 93940, and FRANK PROSCHAN, Department of Statistics, Florida State University, Tallahassee, Florida 32306.*

*FA5.3 Confidence Interval Estimation of Functions of Binomial Parameters, *JEROME R. JOHNSON, Army Materiel Systems Analysis Agency, U.S. Army Aberdeen Research and Development Center, Aberdeen Proving Ground, Maryland.*

*FA5.4 Maximum Likelihood Estimation of Life-Time Distributions for Different Stopping Rules, *L. H. CROW and I. N. SHIMI, Department of Statistics, Florida State University, Tallahassee, Florida 32306.*

FA5.5 Some Stochastic Age Replacement Problems, *B. D. SIVAZLIAN, Department of Industrial and Systems Engineering, The University of Florida, Gainesville, Florida 32601.*

FRIDAY AM, MAY 7 **Alamo Room**

Session: FA6 9:00–12:00
Measurements of Effectiveness in Health and Other Applications

Chairman: JOSEPH L. BALINTFY
School of Business Administration, Department of General Business and Finance, University of Massachusetts, Amherst, Massachusetts 01002

***FA6.1** Decision Criteria in Capital Budgeting, *FERDINAND K. LEVY, Rice University, Houston, Texas 77001.*

***FA6.2** Measuring Performance in the Patient Care Operation of a Hospital, *RICHARD C. JELINEK, The MEDICUS Corporation, 1104 Expressway Tower, Dallas, Texas 75206.*

FA6.3 A Quantitative Approach to Analyzing Regional Health Care Systems, *RICHARD D. SMALLWOOD, Stanford University, Stanford, California 94305.*

FA6.4 A Point-Perspective Model for Hospital Reimbursement, *LARRY SHUMAN and HARVEY WOLFE, Department of Industrial Engineering, University of Pittsburgh, Pittsburgh, Pennsylvania 15213, and C. PATRICK HARDWICK, Blue Cross of Western Pennsylvania, 1 Smithfield Street, Pittsburgh, Pennsylvania.*

FA6.5 Towards a Framework of Health Care Measurement-Medimetrics, *ROBERT M. STARK, Department of Statistics and Computer Science, University of Delaware, Newark, Delaware 19711.*

FA6.6 A Generalized Cost-Effectiveness Model For the Evaluation of Health Programs, *GEORGE W. TORRANCE, Faculty of Business, McMaster University, Hamilton, Ontario, Canada, WARREN H. THOMAS, Department of Industrial Engineering, State University of New York at Buffalo, Buffalo, New York 14214, and DAVID L. SACKETT, Faculty of Medicine, McMaster University, Hamilton, Ontario, Canada.*

FA6.7 A Cost Effectiveness Model for Field Operations of the Western Company, *DON R. BEER, ROBERT D. DRYDEN and DAVID L. LEVY, University of Texas, Arlington, Texas.*

FA6.8 Procedures for Testing Proffered Production and Cost Functions, *JAMES R. MARSDEN, University of North Carolina, Chapel Hill, North Carolina 27514.*

FRIDAY, AM, MAY 7 **Ballroom Foyer**

Session: FA7 9:00–10:15
Simultaneous Session IX

Chairman: THOMAS CRABILL
School of Business Administration, University of North Carolina, Chapel Hill, North Carolina 27514

FA7.1 Analysis of Probabilistic Networks by Markov Chains, *JAMES E. SHAMBLIN, School of Industrial Engineering and Management, Oklahoma State University, Stillwater, Oklahoma 74074.*

FA7.2 Dispersion Characteristics on Performance Times for a Combined Manual and Decision Task, *MARLIN U. THOMAS, Department of Industrial Engineering, University of Michigan, Ann Arbor, Michigan.*

FA7.3 The Dynamics of Corporate Debt Management, *JOHN C. G. BOOT, School of Management, State University of New York at Buffalo, Buffalo, New York 14214, and GEORGE M. FRANKFURTER, College of Business Administration, Syracuse University, Syracuse, New York 13210.*

FA7.4 Anti-Ballistic Missile Allocations to Defend Targets with Time Varying Value Structures, *GARY E. SWINSON, Kentron Hawaii, Ltd., P.O. Box 1488, Balboa, Canal Zone.*

FA7.5 Mathematical Medical Diagnosis: A Status Report, *D. JAMES CROFT, College of Business, Department of Management, University of Utah, Salt Lake City, Utah 84112.*

FA7.6 Air Traffic Controller Performance Effectiveness, *DOROTHY L. FINLEY, The Bunker-Ramo Corporation, Electronic Systems Division, Human Factors Group, 31717 La Tienda Drive, Westlake Village, California 91361.*

FA7.7 An Algorithm for Solving Traveling Salesman Problems in Restricted Contexts, *ROSS E. SCROGGS III and ALAN L. THARP, Computer Science Department, North Carolina State University, Raleigh, North Carolina 27607.*

FA7.8 Surrogated Linear Programming: An Alternative Technique for Solving Linear Programming Problems, *JOHN PAUL DITTMANN and GLENN E. STAATS, University of Missouri – Columbia, Columbia, Missouri 65201.*

FA7.9 Continuous-Review Deterministic Inventory Models and Optimal Control, *JAMES G. TAYLOR, Naval Postgraduate School, Monterey, California 93940.*

FA7.10 A Flexible Enumeration Scheme for Zero-One Programming, *LEON B. ELLWEIN, National Cancer Institute, Bethesda, Maryland 20014.*

FA7.11 Formulations of the Bussing Problem to Achieve Racial Balance, *J. A. WHITE, W. E. BILES, K. E. CASE, and P. M. GHARE, Department of Industrial Engineering and Operations Research, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061.*

FA7.12 Computer Methods for Automatic Diagnosis (COMAD), *H. TRAUBOTH, Computation Laboratory, George C. Marshall Space Flight Center, National Aeronautics and Space Administration, Marshall Space Flight Center, Alabama 35812.*

FA7.13 The Spatial Distribution of Physicians, *RICHARD M. SCHEFFLER, Carroll Hall, University of North Carolina, Chapel Hill, North Carolina 27514.*

FA7.14 Development and Implementation of a Parking Systems Analysis Framework, *RAYMOND H. ELLIS and PAUL R. RASSAM, Peat, Marwick, Mitchell and Company, 1025 Connecticut Avenue, N.W., Washington, D.C. 20036*

FA7.15 O.R. Techniques Relevant to Corporate Planning Function Practices An Investigative Look, *FREDERICK C. WESTON, JR., College of Business, Colorado State University, Fort Collins, Colorado 80521.*

FA7.16 Optimal Inventory Policies in Contagious Demand Models, *A. RAVINDRAN, School of Industrial Engineering, Purdue University, Lafayette, Indiana 47907.*

FA7.17 Convergence Rates for a Method of Centers Algorithm, *ROBERT MIFFLIN, Department of Administrative Sciences, 2 Hillhouse Avenue, Yale University, New Haven, Connecticut 06520.*

FA7.18 Student Degree Program Management by Simulation, *RICHARD F. EARTON, Texas Tech University, P.O. Box 4208, Lubbock, Texas 79409.*

FA7.19 Dynamic Programming and Branch and Bound Approaches for Analyzing Decision Trees in Normal Form, *HERBERT MOSKOWITZ, Purdue University, Krannert Graduate School of Industrial Administration, Lafayette, Indiana 47907.*

FRIDAY AM, MAY 7 **Ballroom Foyer**

Session: FA8 10:30–11:45
Simultaneous Session X

Chairman: THOMAS CRABILL
School of Business Administration, University of North Carolina, Chapel Hill, North Carolina 27514

FA8.1 Application of Order Statistics to Decision Making, *ROBERT A. BROWN, The George Washington University, Washington, D.C. 20006, and KENNETH L. RICH, Sun Oil Company, 1608 Walnut Street, Philadelphia, Pennsylvania 19103.*

FA8.2 The Traveling Salesman in Time, *WAYNE FELTS, Bell Laboratories, Greensboro, North Carolina, and PATRICK KROLAK, Vanderbilt University, Nashville, Tennessee.*

FA8.3 A Methodology for the Analysis of Patient-Care System Time Series Behavioral Data, *RICHARD A. REID, School of Business and Administrative Sciences, University of New Mexico, Albuquerque, New Mexico 87106.*

FA8.4 A Useful Probability Model Based on an Alternating Renewal Process, *MECKINLEY SCOTT, University of Alabama, University, Alabama 35486.*

FA8.5 Selling Management Science to Management—A Package Approach, *RICHARD A. CHASE, Pacific Southwest Forest and Range Experiment Station, Forest Fire Laboratory, P.O. Box 5007, Riverside, California 92507.*

FA8.6 Toward a Technique for a More Exhaustive Evaluation of Urban Area Performance, *J. W. DICKEY, Civil Engineering Department, Division of Environmental and Urban Systems, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061, and J. P. BRODERICK, English Department, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061.*

FA8.7 An On-Line Natural Language Information Retrieval System for Use by Police Investigative Units, *DAVID ALAN BIRD, Department of Applied Mathematics and Computer Science, Washington University, St. Louis, Missouri 63130.*

FA8.8 A Model for Optimum Water Reallocation: Case Study Near Tucson, Arizona, *EDWIN DUPNICK and LUCIEN DUCKSTEIN, Systems Engineering Department, University of Arizona, Tucson, Arizona.*

FA8.9 Application of the Delphi Method to the Psychology of Airplane Pilot Eye Movements, *FRANCIS J. HAINEY, 2724 Monterey Road, San Marino, California 91108.*

FA8.10 Application of Differential Sensitivity Analysis for Optimization of Discrete Operations Research Model, *S. WAZIRUDDIN, Department of Industrial Engineering, Kansas State University, Manhattan, Kansas 66502.*

FA8.11 Estimation of Moments by Quadrature, *DAVID H. EVANS, School of Engineering, Oakland University, Rochester, Michigan 48063.*

FA8.12 Programs Management at Hq USAF, *WILLIAM GRODOWITZ, Directorate of Aerospace Programs, Hq USAF (AF/PRP), Washington, D.C. 20330.*

FA8.13 A Comparison of Bellman's and Howard's Method in Shortest Route Problems, *J. P. SAKSENA, Bharat Heavy Electricals Limited, Ranipur, India.*

FA8.14 Data Base–The Foundation of Information Structures, *ISADORE M. KLAHR, Management Sciences Group, Research Computer Operations, Glass Research Center, PPG INDUSTRIES, Inc., Pittsburgh, Pennsylvania 15238.*

FA8.15 Estimating the Economic Benefits of Outdoor Recreation, *FRANK J. CESARIO, Social and Management Systems Research Section, Battelle Memorial Institute, Columbus Laboratories, 505 King Avenue, Columbus, Ohio 43201.*

FA8.16 A Priority Queuing Model for Hospital Operating Rooms, *SUSHIL SHARMA, Management Consulting Department, Peat, Marwick, Mitchell and Company, 1500 Walnut Street, Philadelphia, Pennsylvania 19102.*

FA8.17 An Application of Utility and Decision Theory in a Planning Environment, *FREDERICK DAVIDSON, McIntire School of Commerce, The University of Virginia, Charlottesville, Virginia 22901.*

FA8.18 An Algorithm for Multi-echelon Production Scheduling, *JACK F. WILLIAMS, School of Business Administration, University of Wisconsin-Milwaukee, Milwaukee, Wisconsin 53201.*

FA8.19 On Packing a Graph, *HENRY D. FRIEDMAN, Department of Electrical Engineering, University of Santa Clara, Santa Clara, California 95053.*

FA8.20 Variability of Elemental Times: A Proposed Method for Precedence Diagramming and Analysis in Assembly Line-Balancing, *TURKAN E. KUMBARACI, Applied Mathematics Department, Brookhaven National Laboratory, Upton, Long Island, New York 11973.*

FRIDAY PM, MAY 7 **Grand Ballroom**

International Buffet Banquet 12:00–1:50

Speaker: W. EDWARD CUSHEN, President
Retiring Presidential Address

FRIDAY PM, MAY 7 **Pioneer Room**

Session: FP1 2:00–5:00
Space Sciences
(Sponsored by: Space Sciences Section)

Chairman. TRAVIS E. PEACE
General Dynamics, P.O. Box 748, Fort Worth, Texas 76101

*FP1.1 Survey of Space Sciences Operations Research, *DON N. TURNER, NASA Headquarters, Washington, D.C*

*FP1.2 Systems Engineering Challenges of the Reusable Manned Space Shuttle Program, *HAROLD E. GARTRELL and ROBERT G. VOSS, Space Shuttle Program/Vehicle Project Office, NASA Manned Spacecraft Center, Houston, Texas 77058.*

*FP1.3 Application of Operations Research Techniques for Planning and Analysis of Space Missions and Space Systems, *CHARLES P. LLEWELLYN and KAREN D. BRENDER, Langley Research Center, Hampton, Virginia.*

*FP1.4 Operations Analysis Applied to Space Station Mission Planning, *FRANKLIN L. ADAMS, The Bendix Corporation, Denver, Colorado, SPENCER A. BULLARD and THOMAS R. HEATON, Martin Marietta Corporation, Denver, Colorado.*

*FP1.5 Logistics Planning for Phased Programs, *JOHN GOODRUM and WARD COOKE, Marshal Space Flight Center, Huntsville, Alabama.*

FP1.6 COMAD—Application to Future Manned Space Vehicles, *RICARDO F. GARZIA, Computer Sciences Corporation, Huntsville, Alabama.*

FRIDAY PM, MAY 7 **Sam Houston Room**

Session: FP2 2:00–5:00
Operations Research in Health and Welfare

Chairman. JOHN R. FREEMAN
The MEDICUS Corporation, 1104 Expressway Tower, Dallas, Texas 75206

*FP2.1 The Use of a Medical History Questionnaire in Routing Patients, *JOHN F. ROCKART, Alfred P. Sloan School of Management, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139.*

*FP2.2 Applications of Simulator-Based Planning Models in Hospital Laboratories, *DAVID VALINSKY, MANUS RABINOWITZ, and M. BARRY DUMAS, Mount Sinai School of Medicine, City University of New York, 11 East 100th Street, New York, New York 10029.*

*FP2.3 Modeling for Incentive Reimbursement, *HARVEY WOLFE, Department of Industrial Engineering, Operations Research and Systems Management, University of Pittsburgh, Pittsburgh, Pennsylvania 15213.*

FP2.4 On Scheduling the Delivery of Babies, *IRWIN W. KABAK, Graduate School of Business Administration, New York University, 100 Trinity Place, New York, New York 10006.*

FP2.5 The Sanative Output of a Health Care System, *RACHEL ROSSER, Department of Medicine, Guy's Hospital Medical School, London Bridge, London, S.E. 1, England, and VINCENT WATTS, Arthur Andersen and Company, St. Alphage House, 2 Fore Street, London E.C. 2, England.*

*FP2.6 The Evaluation of Income Maintenance Programs, *BARTON R. BURKHALTER, Community Systems Foundation, 2200 Fuller Road, Ann Arbor, Michigan 48105.*

FRIDAY PM, MAY 7 Stephen F. Austin Room

Session: FP3 2:00–5:00
Systems Analysis in Government

Chairman: ALAN J. GOLDMAN
Applied Mathematics Division, National Bureau of Standards, Washington, D.C. 20234

*FP3.1 Operations Research for the Federal System of Government, *W. EDWARD CUSHEN, Technical Analysis Division, National Bureau of Standards, Washington, D.C. 20234.*

*FP3.2 An Illustrative Analysis: Predicting the Technology and Character of Passenger Travel, 1975–2000, *EDWIN I. GOLDING, Center for Criminal Justice Operations and Management, Department of Justice, Washington, D.C. 20530.*

*FP3.3 Policy Analysis in the Federal Government, *WALTER A. HAHN, U.S. Department of Commerce, Washington, D.C. 20230.*

*FP3.4 Education for Systems Analysis in Government, *ALVIN W. DRAKE, School of Public Affairs, University of California, Berkeley, California 94720.*

FRIDAY PM, MAY 7 W. B. Travis Room

Session: FP4 2:00–5:00
Information Storage and Retrieval

Chairman: FERDINAND F. LEIMKUHLER
School of Industrial Engineering, Purdue University, Lafayette, Indiana 47907

*FP4.1 On Browsing: The Use of Search Theory in the Search for Information, *PHILIP M. MORSE, Operations Research Center, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139.*

*FP4.2 Cost Effectiveness of Information Transfer Systems, *DONALD W. KING, Westat Research Incorporated, 11600 Nebel Street, Rockville, Maryland 20852.*

*FP4.3 A Stochastic Model of an Information Center, *JACK MINKER, Computer Science Center, University of Maryland, College Park, Maryland 20742.*

*FP4.4 Models for the Design of Data Organization, *JAMES R. ARSENAULT, J F. NUNAMAKER, JR., and A. B. WHINSTON, Purdue University, Lafayette, Indiana 47907.*

*FP4.5 The Development of a Statistical Information System for University and Large Public Libraries, *MORRIS HAMBURG, MICHAEL R. W. BOMMER and LEONARD E. RAMIST, Wharton School, University of Pennsylvania, Philadelphia, Pennsylvania 19104.*

*FP4.6 Measures of Effectiveness for a University Library, *NORMAN R. BAKER and PHILLIP V. RZASA, School of Industrial and Systems Engineering, Georgia Institute of Technology, Atlanta, Georgia 30332.*

FRIDAY PM, MAY 7 **Vaquero Room**

Session: FP5 2:00–5:00
Educational Science
(Sponsored by: Educational Sciences Section)

Chairman: A. W. WORTHAM
Texas A&M University, College of Engineering, College Station, Texas 77843

*FP5.1 The Systems Engineering of Education in Operations Research, *A. WAYNE WYMORE, Department of Systems Engineering, The University of Arizona, Tucson, Arizona 85721.*

*FP5.2 Should OR Education Be Performance Contracted, *RICHARD C. WILSON, Industrial Engineering Department, The University of Michigan, Ann Arbor, Michigan 48104.*

*FP5.3 OR Education for the Practitioner, *FRANK A. TILLMAN, Industrial Engineering Department, Kansas State University, Manhattan, Kansas 66502.*

*FP5.4 Educational Needs for Operations Research in the Durable Goods Industry, *LEONARD R. LAMBERSON, Department of Industrial Engineering and Operations Research, Wayne State University, Detroit, Michigan 48202.*

FRIDAY PM, MAY 7 **Alamo Room**

Session: FP6 2:00–5:00
Optimization Theory

Chairman. FLOYD J. GOULD
Department of Statistics, The Universtiy of North Carolina, Chapel Hill, North Carolina 27514

*FP6.1 Optimization Theory from the Mathematical Programming Viewpoint, *HUBERT HALKIN, Department of Mathematics, University of California, La Jolla, California 92037.*

*FP6.2 Optimality Conditions and Constraint Qualifications, *JON W. TOLLE, Department of Mathematics, University of North Carolina, Chapel Hill, North Carolina 27514.*

FP6.3 Gauss-Seidel Methods in Nonlinear Optimization, *DAVID F. SHANNO, School of Business, University of Toronto, Toronto 181, Ontario, Canada.*

*FP6.4 The Convergence Rates of Some Primal Nonlinear Programming Algorithms, *DAVID G. LUENBERGER, Stanford University, Department of Engineering Economic Systems, Stanford, California 94305.*

*FP6.5 New Applications of Duality in Nonlinear Programming, *R. TYRELL ROCKAFELLAR, Department of Mathematics, University of Washington, Seattle, Washington 98105.*

*FP6.6 All Solutions to Linear Complementarity Problems by Implicit Search, *C. B. GARCIA and C. E. LEMKE, Rensselaer Polytechnic Institute, Troy, New York 12181.*

FP6.7 Equilibrium Points in Nonzero-sum n-person Subadditive Games, *DONALD M. TOPKIS, Department of Industrial Engineering and Operations Research, University of California, Berkeley, California 94720.*

FRIDAY PM, MAY 7 **Ballroom Foyer**

Session: FP7 2:00–3:15
Simultaneous Session XI

Chairman: THEODORE B. SLATTERY
2121 P Street N.W., Suite 213, Washington, D.C. 20037

FP7.1 Variable Work Models for Predicting Course Enrollments, *K. R. BALACHANDRAN, DONALD GERWIN and JOHN AESCHLIMANN, School of Business Administration, University of Wisconsin-Milwaukee, Milwaukee, Wisconsin 53201.*

FP7.2 Adaptive Forecasting of Weekly Series by a Self-Contained Computer Program, *S. P. ZOBEL and R. M. SCAMURRA, Cornell Aeronautical Laboratory, Inc., P.O. Box 235, Buffalo, New York 14221*

FP7.3 The Equivalence of Shortest (Longest) Path Problems to Assignment, Covering and Matching Problems, *PATANJALI S. NANDA, Department of Industrial Engineering, 441 Link Hall, Syracuse University, Syracuse, New York 13210.*

FP7.4 Evaluating Characteristics of Public Transportation Systems in Smaller Urban Areas, *KENNETH W. HEATHINGTON, GILBERT T. SATTERLY and WILLIAM L. GRECCO, Joint Highway Research Project, Purdue University, Lafayette, Indiana 47907.*

FP7.5 Urban Models – Which Way to Go, *MYRON R. ROSENTHAL, Graduate School of Business, Loyola University, 820 N. Michigan Avenue, Chicago, Illinois 60611.*

FP7.6 Dynamic Programming and Fuzzy Allocation Processes, *AUGUSTINE M. O. ESOGBUE, Department of Operations Research, Case Western Reserve University, Cleveland, Ohio 44106, and VENGALATHUR RAMESH, Department of Statistics and Operations Research, University of North Carolina, Chapel Hill, North Carolina 27514.*

FP7.7 A Set Covering Approach to the Web Width Determination, *GARY M. ANDREW, School of Business Administration, University of Minnesota, Minneapolis, Minnesota 55455, and MING-TE LU, School of Business, St. Cloud State College, St. Cloud, Minnesota 56301.*

FP7.8 Towards Cybernetic Loading Models: A Complex Linear Flow Model Approach, *FRANCISCO SAGASTI, Management Science Center, University of Pennsylvania, Philadelphia, Pennsylvania 19104.*

FP7.9 Efficient Heuristic Rules for the Warehouse Location Problem, *BASHEER M. KHUMAWALA, Graduate School of Business Administration, University of North Carolina, Chapel Hill, North Carolina 27514.*

FP7.10 A Constrained Shortest Path Algorithm, *PAUL A. JENSEN, Department of Mechanical Engineering, University of Texas, Austin, Texas, and RONALD C. BERRY, IBM Corporation, Austin, Texas.*

FP7.11 A Two-Product Inventory Control Model with Substitution, *SATISH J. KAMAT, Department of Industrial Engineering, New Mexico State University, Las Cruces, New Mexico 88001.*

FP7.12 A Parameter Perturbation Procedure for Obtaining a Solution to Systems of Nonlinear Equations, *J. C. HELM, Department of Industrial Engineering, Texas A & M University, College Station, Texas 77843.*

FP7.13 Allocation and Expansion Policies for the Fixed Capacity Resources of a Decentralized Organization, *WILLARD N. ANDER, Industrial and Systems Engineering Department, University of Houston, Houston, Texas 77004.*

(Continued)

FP7.14 A Monte Carlo Approach to Crew Scheduling, *JOHN LOO, BURTON T. O'DONALD and IRVIN R. WHITEMAN, Eastern Air Lines, Inc., International Airport, Miami, Florida 33148.*

FP7.15 Optimal Service Rate Selection in Piecewise Linear Markovian Service Systems, *BILL MITCHELL, Operations Research Center, University of California, Berkeley, California 94709.*

FP7.16 A Mathematical Model of the Value of Achievement Test Information, *PAUL D. PINSKY, Institute for Mathematical Studies in the Social Sciences, Stanford University, Stanford, California 94305.*

FP7.17 Operations Research and the Prison/Parole System – A Markov Example, *PIERRE M. TULLIER, Univac, Sperry Rand, P.O. Box 6248, San Diego, California 92106.*

FRIDAY PM, MAY 7 **Ballroom Foyer**

Session: FP8 3:30–4:45
Simultaneous Session XII

Chairman: THEODORE B. SLATTERY
2121 P Street N.W., Suite 213, Washington, D.C. 20037

FP8.1 The Generalized Lattice Point Problem, *FRED GLOVER, School of Business, University of Colorado, Boulder, Colorado 80302, and DARWIN KLINGMAN, School of Business, University of Texas, Austin, Texas 78712.*

FP8.2 Some Common Errors Associated with Regression Analysis, *MURLE J. ATHERTON, The International Nickel Company, Inc., Suffern, New York 10901.*

FP8.3 Surveillance Aircraft Cost Model, *MICHAEL B. BRYANT and PATRICK SMOCK, MASTS PCMO AVSCOM, Mart Building, 12th & Spruce Streets, St. Louis, Missouri.*

FP8.4 Study of the Police Patrol Vehicle, *HERBERT G. LUDWIG, Industrial Engineering and Operations Research Department, 632 Putnam, Wayne State University, Detroit, Michigan 48202.*

FP8.5 Computer Simulation of Initial Attack on Forest Fires, *FREDERICK W. BRATTEN, Pacific Southwest Forest & Range Experiment Station, Forest Fire Laboratory, P.O. Box 5007, Riverside, California 92507.*

FP8.6 Computer-Optimized Bus Run-Cutting Algorithm: The COBRA MODEL, *EDWARD LIEBERMAN and R.J. JABBUR, General Applied Science Laboratories, Inc., Westbury, Long Island, New York.*

FP8.7 An Investigation of the Eye Movements of Pilots Engaged in Visual Search Under Actual Conditions, *JOHN L. SMITH, Air Force Institute of Technology, Wright-Patterson Air Force Base, Ohio 45433.*

FP8.8 Integer Solutions to Convex or Concave Programming Problems, *JOEL WEISMAN and KRISHNAN CHITKARA, University of Cincinnati, Cincinnati, Ohio 45221.*

FP8.9 Geometric Programming and the Optimal Design of a Water Quality System, *J.G. ECKER, Mathematics Department, Rensselaer Polytechnic Institute, Troy, New York 12181.*

FP8.10 The Linear Complementarity Problem in Complex Space, *CHARLES J. McCALLUM JR., Bell Telephone Laboratories, Inc., Holmdel, New Jersey 07733.*

FP8.11 Press Run Sequencing for Multi-Edition Periodicals, *SHERIF M. NASR and JOSEF LUBENOW, R.R. Donnelley and Sons Company, 2223 Martin Luther King Drive, Chicago, Illinois 60616.*

FP8.12 The General Truck Dispatching Problem, *JACQUES H. DALLOZ, Management Science Center, University of Pennsylvania, 4025 Chestnut Street, Philadelphia, Pennsylvania 19104.*

FP8.13 Labor Idle Time versus Manufacturing, *PAUL Z. CUMMINS II, Corporate Management Systems, Carrier Corporation, Carrier Parkway, Syracuse, New York 13201.*

FP8.14 A Variant of Klein's Method for Minimal Cost Flows, *G.E. BENNINGTON, North Carolina State University, Department of Industrial Engineering, Raleigh, North Carolina 27607.*

FP8.15 Steady State Waiting Time in a Multi Center Job Shop, *ASHA SETH KAPADIA, Arthur D. Little, Inc., Cambridge, Massachusetts 02140.*

FP8.16 Optimal Issuing Policies for Perishable Inventory, *WILLIAM P. PIERSKALLA, Department of Industrial Engineering and Management Science, Northwestern University, Evanston, Illinois 60201 and CHRIS D. ROACH, Computer Science/Operations Research Center, Southern Methodist University, Dallas, Texas 75222.*

FP8.17 Admission-Scheduling Model for Hospital, *ISHWAR GUPTA, Hospital Systems Consultant, Rush Presbyterian St. Luke's Medical Center, Chicago, Illinois, and M. ZIA HASSAN, Department of Industrial Engineering, Illinois Institute of Technology, Chicago, Illinois 60616.*

FP8.18 The Direct Approach to Approximate Decision Models, *JOHN O. McCLAIN, Graduate School of Business and Public Administration, Cornell University, Ithaca, New York.*

FP8.19 Algorithms for Scheduling Jobs in a Flowshop, *JATINDER N. D. GUPTA, Department of Industrial Engineering, The University of Alabama in Huntsville, P.O. Box 1247, Huntsville, Alabama 35807, and ALBERT R. MAYKUT, U.S. Army Missile Command, Huntsville, Alabama 35807.*

FP8.20 Appraising Feasibility and Maximal Flow Capacity of a Network, *ALAN W. McMASTERS, Department of Operations Analysis, Naval Postgraduate School, Monterey, California 93940.*

Abstracts

*WA1.1. Non-Equilibrium Theory of Queueing Systems, N. U. PRABHU.

This is a survey of some recent work on queues in non-equilibrium, when the traffic intensity (i) equals one and (ii) exceeds one. In a single server queue with Poisson arrivals and exponential service times the limit distributions of queue length and waiting time, reduced with appropriate location and scale parameters, are found to be the normal in case (ii) and the one-sided normal in (i). In the single queue with traffic intensity one, limit distributions are also obtained for the idle time and busy cycles. Finally, priority queues in heavy traffic have also been investigated.

*WA1.2. A Survey of Research in Optimal Dynamic Control of Queuing Systems, THOMAS B. CRABILL.

This paper presents a survey of research up to the present time in the optimal control of queuing systems. In addition, some suggestions for future work are offered. The emphasis is on the models considered, the general techniques employed, and the results obtained, rather than on the specific analytical manipulations of the authors.

*WA1.3 Convexity in the Descriptive Distributions of Congestion Systems, JULIAN KEILSON.

Log-concavity and log-convexity have frequent occurrence in passage time densities and transition probabilities of congestion systems. The incidence of these properties, their origin and their practical significance will be discussed.

*WA1.4. Busy Period Analysis of a Time-Sharing System Modeled as a Semi-Markov Process, U. NARAYAN BHAT and RICHARD E. NANCE.

Previous methods consider the steady state behavior of the time sharing systems neglecting their transient characteristics such as the busy period distribution. Using the special features of the process, a simple computationally efficient procedure is developed for the busy period analysis of a system in which jobs originate at a finite number of peripheral units, demand service for exponential lengths of time and get served with a feedback type discipline. This analysis enables determination of the probability distribution of the number of tasks in system at an arbitrary time point as well as a task completion epoch.

WA1.5. Cyclic Queues with Bulk Arrivals, IGAL ADIRI.

This paper deals with a single-server station (a computer) with Poisson arrivals and each customer demanding a random number of jobs (programs). Two cyclic disciplines are investigated: (a) *continuous job service*—customer demanding more service than already given returns to the end of the queue and the cyclic procedure is repeated until his demand has been satisfied; (b) *intermittent job service*—under which continuity is limited to a predetermined time interval; if uncompleted by then, the job moves to the end of the customer's demand (job queue) and the customer returns to the end of the customer queue.

WA1.6. Control of Queues, S. SUBBA RAO and K. P. K. NAIR.

The control of congestion can take many forms depending on the nature of the queuing system considered. To be effective, control implies a dynamic environment and a

review and updating of information. Control in queues can be achieved i) by controlling the arrival pattern, or ii) by controlling the Service Mechanism, or iii) by controlling the system as a whole. Two major approaches to this problem are through Optimization Theory and Statistical Decision Theory. This paper presents some working ideas as to the control of queues through a SQC (Statistical Quality Control) type approach.

WA1.7. On the Relation Between Customer and Time Averages in Queues with Some Applications, SHELBY BRUMELLE.

A general framework is established for relating customer and time averages. The best known example of a relation of this type is that between the time average number in queue and the average delay in queue of a customer. One application of the general theory is the verification of this relation for parallel server queues with stationary input (i.e. the interarrival and service times form a stationary sequence of random vectors). Formulae relating the time average moments and distribution of the number in queue to the moments and distribution of a customer's delay also follow.

***WA2.1.** An Analysis of Preferential Area ABM Defenses, STEPHEN B. DEUTSCH.

A preferential ballistic missile defense can defend many targets from one site. A defense-conservative bound to its effectiveness can be obtained by permitting the defense to allocate interceptors with complete knowledge of the attack allocation. This paper assumes that the defense lacks such knowledge. Realistic assumptions—unreliable weapons and targets with unequal values and vulnerabilities—are made. The defense should abandon some targets but defend all others "to the death." One key feature of its strategy is the choice of probabilities with which to defend each target. An offense optimized against this doctrine generates a defense-conservative bound to preferential defense effectiveness. For some example cases examined the two bounds are reasonably close.

***WA2.2.** The Effect and Use of Air Power in the Middle East, JOSEPH ALON.

The following topics will be discussed: The choice of equipment, training, strategy and tactics, for specific but varied Air Force roles. The effectiveness and limitations of air power. The human factor and motivation in planning and forecasting operations. All these and much more played a part in determining the outcome of the Six Day War and affect tactical thinking for the future with all its possible developments. There will also be a short film (about 3 minutes)—"Six Hours in June".

***WA2.3.** The Requirement for Air Force Tactical Forces in the 1980's, RICHARD G. RHOADES.

This paper outlines the environment in which future Air Force tactical forces must be prepared to operate, discusses how this environment will shape the requirement for future forces, and points out that new tactical capabilities must be made available. The future capabilities required are outlined in general terms for the major elements of tactical fighters and attack, reconnaissance, airlift, command, control and communications, and counter insurgency. The paper concludes that future technology will be adequate to provide these capabilities only if a vigorous research and development climate is maintained.

***WA2.4.** A Simulation Model for Scheduling Randomly Occurring Airlift Demands, DAVID T. H. CAMPBELL.

The Navy's requirements for movement of personnel and material to provide tactical support of its operating forces are characterized by random occurrence with low frequency for most origin/destination pairs, small loads, and high priority. This paper discusses. (1) A simulation model developed to determine the preferred types, numbers, and basing of transport aircraft to satisfy these requirements; (2) Its applicability to long range program planning, to immediate problems of type and location of assets, and to evaluation of contractor proposals; and (3) Some of the problems encountered in communicating the results to the planners.

*WA3.1. Corner Polyhedra and Related Inequalities, RALPH E. GOMORY.

This paper will discuss the present state of the art with respect to corner polyhedra and the inequalities that can be derived from them for integer and mixed integer programming. Continuous functions related to corner polyhedra will be discussed.

*WA3.2. Data Manipulation of Integer Programming Problems, G. ANTHONY GORRY, JEREMY F. SHAPIRO and LAURENCE A. WOLSEY.

The efficiency of group theoretic algorithms on a given IP problem is largely dependent on the sizes of the groups. This paper contains some procedures for controlling these sizes, primarily by reducing the magnitudes of the coefficients. The resulting approximate problem can be used to find an optimal solution to the original problem. One procedure allows the data manipulation to be made if necessary after an optimal LP basis has been found. Approximation errors can be reduced by generalized Lagrange multiplier methods. Also given are applications to fixed charge and mixed IP problems, and computational experience.

*WA3.3. Primal Methods with Convexity Cuts, RICHARD D. YOUNG.

This paper explores the use of convexity cuts in the context of an algorithm that maintains a primal feasible, integer solution as the current basic solution in each tableau. In primal algorithms employing Gomory cuts, the (all integer) cut is generated from a tableau with an all integer constant column. This cut is identical to a fractional cut that could be used to remove an adjacent (fractional) extreme point. We use this relationship to generate convexity cuts in a primal feasible and integer feasible tableau.

*WA3.4. Integer Programming and Convex Analysis, EGON BALAS.

A recent, geometrically motivated approach to integer programming generates cutting planes (intersection cuts) from the intersection of the extended edges originating at some vertex of the feasible set, with the boundary of a convex set whose interior contains the given vertex but no feasible integer point. The larger the convex set whose boundary is intersected, the stronger the cut tends to be. Convex analysis can be used to construct sets that are as large as possible within the limits of the above requirement. In a previous paper we did this via maximal convex extensions of the n-dimensional ball and octahedron. The present paper discusses additional properties of these constructions, which enable us to use them in a new context.

*WA3.5. Transformation of Integer Programs to Knapsack Problems, GORDON H. BRADLEY.

It is shown that any bounded integer linear programming problem can be transformed to an equivalent integer linear programming problem with a single constraint and the same number of variables. The original integer problem and the equivalent single constraint problem have identical feasible integer solutions and thus the single constraint problem may be solved instead of the original problem. It is also shown that any bounded integer programming problem is equivalent to a problem of optimizing a linear function subject only to bounds on the function and bounds on the variables. The results are extended to problems with nonlinear constraints.

WA3.6. Constraint Classification in Zero-One Integer Programming, V. J. BOWMAN.

This paper shows that the constraints of a 0–1 integer program can be reduced to a finite set. While this set is quite large, similarity under permentation and rotations further reduce the size. A combinatorial algorithm is given for classifying the constraints. The significance of these classifications with respect to cutting plane techniques is discussed.

WA3.7. Enumerative Algorithms for Nonlinear Extreme Point Mathematical Programming Problems, H. R. LOVE, M. KIRBY and KANTI SWARUP.

The paper considers enumerative algorithms for solving extreme point mathematical programming problems: maximize CX, subject to X in S and X is an extreme point of a

given convex polyhedron. A new algorithm developed by the authors is presented and some enumerative procedures developed by others are summarized. Some numerical examples are also included.

WA3.8. A Mixed Integer Programming Algorithm, A. RIESCO and M. E. THOMAS.

This paper presents a multistep solution procedure for solving mixed-integer programming problems that are separable and nonlinear in the continuous variables of the objective function and linear in the constraints. The procedure developed solves a continuous nonlinear programming problem and a discrete optimization problem at each iteration of the algorithm. Lower and upper bounds on the optimal objective function value are generated at each iteration and convergence on the optimum is guaranteed in a finite number of steps.

*WA4.1.

Problems and Issues in the Evaluation of Manpower Programs: An Overview, MICHAEL E. BORUS.

The paper begins with a review of the literature evaluating manpower programs with special emphasis on the methodological and practical problems faced by early evaluators. The evolution of techniques to solve these problems is next considered followed by an assessment of the state of the art. The paper concludes with a statement of those questions still unresolved and the author's views on the most effective course of action for future research.

*WA4.2. A Cost-Effectiveness Analysis of the In-School and Summer Neighborhood Youth Corps, ERNST W. STROMSDORFER.

The Neighborhood Youth Corps seeks to increase the graduation rate of high school students, as well as increase their employability and earnings after leaving high school through a work and income transfer program designed to reduce the opportunity costs of school attendance. Multiple regression analysis of a stratified weighted sample of 1,200 NYC enrollees and controls from 60 projects taken from the 1120 projects in operation in FY 1966 and 1967 is used to measure the program's cost-effectiveness. Methodological issues are discussed which impinge upon the accuracy and generality of the findings and policy recommendations.

*WA4.3. An Assessment of Four Manpower Programs, PETER S. BARTH.

Almost all evaluations of Federal manpower programs have suffered from at least one of several analytical shortcomings. This paper will describe a project that will attempt to evaluate four major manpower programs, JOBS, MDTA (Institutional), NYC (Out-of-School) and Job Corps, that will overcome many of these shortcomings. A survey of trainees from these programs and a control-comparison group has been conducted. Unlike most earlier evaluations the sample size is fairly large–close to 9,000 persons–it is not restricted to a single geographic region, it is longitudinal and consists of four waves of interviews, and program information has been collected.

*WA4.4. Towards an Optimum Military Personnel Recruitment and Retention Policy, M. LANDO and D. O'NEILL.

The military compensation structure and hiring practices are analyzed to see how they relate to rational personnel management objectives. The analysis concentrates on three aspects. (1) hiring and recruiting practices; (2) the pattern of relative compensation by length of service, and (3) the division of total income as between cash, income in kind, and working conditions. A utility-based model of retention behavior is developed in terms of the three types of income. Some empirical materials are introduced to indicate possible order of magnitude effects of reallocations.

*WA5.1. Models of the Production and Deterrence of Crime, ALFRED BLUMSTEIN.

Crime is a phenomenon whose occurrence is a reflection of laws, of enforcement

practice, and of individual behavior. In this paper, we develop theory that begins with assumptions about individual rational behavior, emphasizing risk-taking considerations, and extending to the social forces acting on the administration of punishment. Empirical evidence is used to explore the validity of the theories.

*WA5.2. A Systems-Analytic View of Criminal Justice in Virginia, DUNCAN BAILEY, LEE McPHETERS and CHARLES SCHOTTA.

Building upon the Blumstein-Larson model, the entire Criminal Justice System of the Commonwealth of Virginia (police, prosecutors, courts, and corrections) is modeled for computer simulation. The general model utilizes data on costs, transitional probabilities, work loads, and incidence of crime by type for 1968, 1969 and 1970 for each city, county, and town in the Commonwealth. Additionally, certain economic, demographi and sociological data provide secondary input to the model. The use of this model as a planning and evaluation instrument provides the CJS resource allocation decision-maker with "a priori" estimates of the cost effectiveness of alternative resource allocation patterns and "a postoriori" evaluations of the impact of already-concluded specific changes in resource allocation patterns.

*WA5.3. Simulation Model of a Municipal Detective System, JOSEPH FOLK.

This paper presents a computer simulation model for analyzing operational practices in the investigative branch of a municipal detective system. Objectives of the simulation include a study of various case-assignment, case-investigation, and manpower-allocation policies. Sample runs are presented and evaluated, and extensions and limitations of the model are discussed. The Boston Police Department cooperated with the author by providing an observational base for developing the model.

*WA5.4. Operations Research at the St. Louis Metropolitan Police Department, NELSON B. HELLER.

As of December, 1970 the number of active operations research projects at the St. Louis Metropolitan Police Department had grown to six, each being conducted by a team of Department personnel and students from local universities. The projects include computer design of police beats, implementation of proportional rotating schedules, expansion of the real-time motor vehicle system, measuring the seriousness of called for service incidents, strategies for the recovery of stolen vehicles, and "natural language" inquiries as input to real-time crime data retrieval system. Progress on each of the projects and some of the author's personal experiences are discussed.

*WA5.5. Quantitative Models of Criminal Courts, JOHN B. JENNINGS.

Criminal courts are institutions which have been subjected to tremendous growth stresses in recent years. In general, the expansion of court resources has lagged well behind the rise of case loads, resulting in ever-growing delays, detention facilities, and disillusionment with the entire criminal justice system. Only recently have the techniques of operations research begun to be applied to these problems. This paper summarizes some recent work in the development of quantitative models of court operations and discusses promising areas for further work of this type. The models discussed include analytic and simulation models of case flow, scheduling, and courtroom activities.

*WA5.6. Criminal Justice Analyses in New York City, PETER R. GRAY.

With the aid of Federal funds available under the Omnibus Crime Control and Safe Streets Act of 1968, New York City is undertaking a number of programs to change the city's criminal justice system. In establishing priorities and in developing specific programs a number of analyses have been useful. This paper will briefly describe the overall city criminal justice system and then focus on specific studies that have contributed to criminal justice planning and operations. The discussion will include comments concerning the characteristics of studies that appear to be important in determining their usefulness.

*WA6.1. Chaos and Control, ROBERT G. BROWN.

Research observes environments, constructs models, and tests predictions (under conditions that place the model in jeopardy) to improve the models. The history of production shows trends in complexity of control required by large organizations and proliferation of variety. Decision models have grown in realism, through insight gained in simple cases, ORSA's base of knowledge, and enhanced computing power.

This paper tests those trends, but the test may effect the environment. The self-fulfilling prophecy is a feasible technique for production decisions.

The prophecy concerns itself with a hierarchy of cybernetic holons, which concentrates on external relationships among holons, and relies on internal homeostasis.

*WA6.2. Dynamic Models for Capacity Expansion and Location, DONALD ERLENKOTTER.

Traditionally, capacity location problems have been defined in a static context. Here we present models and solution methods for planning sizes and locations of capacity expansions under conditions of growing demand. The simplest models are project sequencing problems related to the traveling salesman problem, but models become more complicated with the introduction of cost interdependencies between projects. All solution methods have in common the exploitation of optimal timing properties for the various expansions. The range of methods developed extends from simple ranking approaches for special situations, to dynamic programming methods for moderately sized problems, to incomplete dynamic programming approximations for large problems.

*WA6.3. A Decomposition Algorithm for Arborescence Inventory Systems, BASIL A. KALYMON.

Arborescence structures model multi-echelon production and inventory systems in which each facility requires input from a unique immediate predecessor. Assuming known demands, and no backlogging, the objective is to schedule production over a finite planning horizon to minimize production and holding costs. An algorithm which decomposes this problem by facilities is developed. The algorithm is applicable to systems in which at all facilities with followers in the system the production costs consist of a set-up charge plus linear costs and holding costs are linear. General costs are permitted at the lowest echelon facilities (those without followers) with special computational efficiency resulting when these costs are concave.

*WA6.4. The Roles of the Man and the Computer in Production Planning, CURTIS H. JONES.

This paper will discuss the relative strengths and weaknesses of experienced human decision makers and effective computer programs. It will attempt to demonstrate how both can be combined to provide effective workforce level and production rate decisions. Particular attention will be paid to the development of mathematical techniques that can be used to generate effective starting answers and the construction of the kinds of displays that will stimulate the manager to build on, and to improve these solutions.

WA6.5. Production Scheduling Using Network Flows Under Uncertainty, GORDON P. WRIGHT and JUAN PRAWDA.

This paper extends Connors and Zangwill's work in Network Flows Under Uncertainty to the convex cost case. In this paper, the extended Network Flow Under Uncertainty algorithm is applied to compute optimal N-period production and delivery schedules of a single commodity in an inventory system with convex costs. Given an initial production capacity for N periods, the optimal production and delivery schedules for the entire planning horizon are characterized by the flows through paths of minimal expected discounted cost in the network. By transforming the network flow problem to a mathematical programming problem and optimizing the latter, optimal schedules are computed when the system is subject to (joint) linear production and delivery constraints in each period.

WA6.6. Deterministic Production Planning with Concave Costs and Capacity Constraints, MICHAEL FLORIAN and MORTON KLEIN.

A multi-period single commodity production planning problem is studied in which known requirements have to be satisfied. The model differs from earlier well-known studies involving concave cost functions in the introduction of production capacity constraints. The structure of an optimal solution is characterized and then used in a simple dynamic programming algorithm for problems in which the capacities are the same in every period. Both the non-backlog and backlog allowed cases are considered.

WA6.7. Manpower Planning for Aircraft Manufacturing Operation, H. F. CHIANG and C. E. CLARK, JR.

A time sharing program has been developed which will accept as inputs the delivery schedule of an aircraft manufacturing program and its production period, and will give as outputs weekly manpower requirement by cost center. The output provides a basis for transferring work force from one cost center to another, thus avoiding costly temporary hiring and layoffs. Learning curve was used to compute hours required and statistical techniques were used in spreading total hours over a given period to assure smooth buildup.

WA7.1. Poisson Processes in Random Environments, RICHARD F. SERFOZO.

We introduce a stochastic process which operates in a randomly changing environment such that (a) within a given environment the process behaves like a homogeneous Poisson process with an intensity which is a function of the environment, and (b) the environmental changes are not affected by the process. We present results on the transient and limiting behaviour of these processes when the environmental changes are Markovian and show how these results generalize for an arbitrary environment process.

WA7.2. Regression Analysis of Class Differences, BARR ROSENBERG.

The problem considered is regression analysis of a large population of individual cases, each characterized by a parameter vector; the values of one or more of these parameters vary from one class to the next along several partitions of the population into mutually exclusive classes (each partition reflecting some kind of classificatory information). The problem is run as a single regression, with artificial variables introducing cross-class parameter variation. Various conceptual and computational simplifications are discussed. The problem can be reduced by partitioned inversion, with the block of artificial variables relating to the finest partition treated separately.

WA7.3. Interactions of Cost, Reliability and Performance Factors in Advanced Space Systems, DAVID K. BIVINS.

The interaction of cost and performance of aerospace systems has been widely studied, but for systems employed in complex missions, cost and performance cannot be divorced from the reliability sought: greater system reliability can be achieved at added cost by duplicating critical components; a system operated beyond designed performance limits becomes less reliable in subsequent use. Reliability must be defined in the mission context. For example, reliability and performance of a launch vehicle-spacecraft-ground support-pilot system interact differently for missions of different stringency; reliability may be redefined in many cases as the probability of mission success.

WA7.4. Optimum Lot Sizes for a Shop-Warehouse System, MOHAMED E. TAYMOUR.

The relation between lot sizes, lead-times and total system costs, including in-process inventory, in a shop-warehouse system is investigated. It is shown that the lead-time of an order is dependent on its lot size and on the lot sizes of all other orders sharing any work-center with that order. Exact solutions for optimum lot sizes under these conditions are unattainable. An approximate method that requires minimum computational effort is shown to result in a cost reduction when compared to other

methods for computing optimum lot sizes. Simulation results indicate cost reductions can be considerable.

WA7.5. Stochastic Interference in Item Processing Systems, ROBERT H. BEEDE.

An investigation of existing item processing equipment has revealed that a major cause of inefficiency is stochastic interference both among the various processing operations and between these operations and the external environment. This condition is most severe when men perform some of the operations. This report presents techniques for (1) identifying, isolating, and measuring stochastic influences and (2) eliminating or reducing their effects. Particular attention is given to Post Office parcel processing systems.

WA7.6. A Routing Problem in City Solid Waste Collection, RICHARD M. WYSKIDA and JATINDER N. D. GUPTA.

The problem of city refuse (popularly known as garbage) collection is becoming increasingly complex as time progresses. This paper analyzes the problem of refuse collection for the city of Huntsville, Alabama and suggests a logical approach for determining the number and location of routes so as to minimize the equipment requirements and achieve an equitable distribution of work among the employees The logical approach to the problem does not yield an optimal solution; however, an optimal solution appears to be undefinable. The essential features of the proposed approach are its adaptability, feasibility and ease of understanding.

WA7.7. Surveillance of Surface Water Quality: Design and Operation of Data Networks, CHESTER C. KISIEL.

The problems of monitoring the quality parameters of surface water in streams and estuaries are examined from three points of view: surveillance, regionalization, and mass accounting of these parameters. Spatial, temporal, and operational considerations enter into the formal study of surveillance networks. Formulated is an objective function that includes cost of sampling, opportunity losses for not sampling, and benefits from information obtained. Constraints are technological, budgetary, social or legal. Use of regional models seems appropriate to rationalize the efficiency of data-taking procedures.

WA7.8. Sequencing Aircraft at an Air Terminal, JOSEPH S. MATNEY and WALTER C. GIFFIN.

Sequencing of arriving and departing aircraft at a single air terminal operating under IFR conditions is considered. The current FAA procedure calls for first-come, first-served sequencing with arrivals having priority over departures. Models for other sequencing rules are developed and the pertinent characteristics (mean waiting time for each aircraft type, mean number of operations per unit time, etc.) are compared to the current FAA procedure characteristics. In addition, optimal sequencing models are investigated which provide sequences that minimize the mean waiting time and maximize the mean number of operations per unit time.

WA7.9. Shortest Route Subject to Improvements Through Dynamic Programming, S.P. BANSAL and S. KUMAR.

The problem of obtaining a shortest route from a given starting station to another terminal station in a network of stations is in general a basic one in Operations Research and particularly routing in a network. In this paper, the possibility of improvements in the existing path joining any two stations is envisaged. The problem considered is that of deciding which link or links should be improved in order to obtain the shortest path between two stations for a given number of improvements in the entire route. Functional equations using Bellman's Principle of optimality have been developed and solved for two different cases. Numerical examples have been provided to illustrate the computation.

WA7.10. A Decision Model for Evaluating Potential Change in Instructional Programs, J. P. AMOR and JAMES S. DYER.

This paper presents a model designed to assist elementary school principals in the process of selecting educational areas which should receive additional emphasis. For each educational area, the model produces an index number which represents the expected "value" per dollar spent on an instructional program appropriate for strengthening that area. The calculation of the index number for a particular area depends on the following factors: (1) the relative importance of that area; (2) the "utility," or "value" to the decision maker, of making an improvement in that area, given the current level of performance; (3) the probability distribution of the results of implementing a particular type of improvement program for that area, given the current level of performance; and (4) the cost of the above mentioned program.

WA7.11. Risk Properties of Multiattributed Utility Functions, RALPH L. KEENEY.

The usefulness of risk properties, such as risk aversion, in assessing one attribute utility functions is well-known. In this paper, we define some risk properties relevant to multiattributed utility functions and indicate their usefulness in assessing such functions. First the concepts of risk independence and conditional risk aversion are defined. From this we obtain a conditional risk premium. A number of results useful for simplifying the assessment of multiattributed utility functions given certain risk properties are stated. The concept of risk independence is then generalized to what is called utility independence which permits extension of the original results to many additional situations.

WA7.12. Evaluation by Simulation Saves Construction Dollars, AUSTIN E. BRANT, JR. and PATRICK J. McAWARD, JR.

Through the application of computerized simulation techniques, the future operation of a proposed airport can be evaluated prior to construction. TAMS developed and used a fast-time computer simulation to evaluate the performance of the proposed Dallas-Fort Worth Regional Airport. This simulation traces aircraft operations between arrival and departure, including runway, taxiway and gate selection and occupancy under various operating conditions. Output of the program provides total travel time and cost per aircraft type and by airline, delay times and causes and causes, facility utilization frequencies and a computer generated motion picture showing aircraft ground movements in 1975.

WA7.13. Computer-based Laboratories for Teaching O.R. and Statistics, AMRIT L. GOEL and P. NANDA.

This paper describes the use of computer-based labs for conducting 'experiments' as a supplement to the class-room teaching of O.R. and Statistics. Using simulation and sampling techniques, the computer performs 'experiments' and analyzes results under student control to demonstrate, clarify and reinforce concepts learned in the class-room. The experiments are also employed for handling O.R. problems using statistical methods, for example: Study of the sensitivity of the optimal L.P. solution using the concept of confidence intervals when the estimates for the constraint matrix are subject to uncertainty; the use of statistical experimental designs in simulation studies of complex industrial systems; and illustration of the power of the variance reducing techniques in increasing the efficiency of simulation studies.

WA7.14. Systems Evaluation by Discrete Markov Event Chain Analysis, GERALD R. HARP.

Most system evaluations are performed by comparing an arbitrary measure of merit obtained by combining a number of weighted performances characteristics. This paper describes an evaluation procedure whereby systems whose operations are amenable to Markov event analysis may be evaluated in terms of the effects of the evaluation elements—i.e. system to be evaluated, interactive systems, environment and operation policy—summarized into a probability of operations outcome with all performance

characteristics automatically weighted. This method results in a presentation of results which graphically indicates the more important areas of interaction and which is intuitively appealing to operations oriented decision makers.

WA7.15. Systems Analysis in the Courts, WILLIAM H. BLEUEL.

Civil and criminal courts have system characteristics which are quantifiable and subject to analysis in the same manner as any modern business enterprise. A major goal of systems analysis is to discover the methods by which this rate of disposition of cases may be significantly increased. The constraints which must simultaneously be maintained include governmental budget limitations and the limitations of personnel in terms of judges as well as defense counsel. This paper will present the results-to-date of a systems analysis currently being performed on the criminal courts in Monroe County, New York.

WA7.16. On the Solution to Lanchester-Type Equations with Variable Coefficients, JAMES G. TAYLOR.

We obtain solutions to Lanchester-type equations for combat between two homogeneous forces when the attrition rates are variable under general conditions. These results apply with either time or force separation as the independent variable. Our results are applicable to combat between forces using weapons with the same effective range (attrition commencing for both sides at the same time) but not necessarily the same range (time) dependence. We also solve the problem for weapon systems with different effective ranges. Solutions are developed in terms of tabulated functions, but series solutions and solution of equivalent integral equations are discussed.

WA7.17. The use of Network Theory in Determining Corporate Planning Strategies, GAYLE C. FOHRELL.

An ever increasing number of corporations are beginning to put an extensive amount of effort into developing Corporate Planning Strategies. The planning model developed for Weyerhaeuser's Manufactured Panel and Molded Products Division aides in determining these strategies. The model, which is used for quarterly and annual planning, uses a revised version of Ford and Fulkersons' Out-of-Kilter Algorithm. A game formulation of the problem is used to determine Weyerhaeuser's competitive advantage under different market conditions and also aides in the following decisions:

1) distributing products from mills to markets
2) planning for new facility locations
3) allocating orders to mills.

WA7.18. A Model for Interurban Travel in the United States, PHILIP M. PEARSON.

The objective of this paper is to present a systems theory model of interurban travel. The model requires that measures are made on each component of an intercity travel system consisting of origins, destinations and modal travel links. The components are connected to form an interdependent mathematical description of the entire system. The unique sensitivity of the model can then be used to determine the traffic consequences due to changes in any link of the system. The model is developed for the domestic airway system. A further example considers travel by four modes in the Northeast Corridor.

WA7.19. A Lagrangian Formulation of the Journal Selection Model, D. H. KRAFT and T. W. HILL, JR.

In this paper we investigate a Lagrangian formulation of the journal selection model due to Kraft and Hill. A lemma describing the optimal decision rule is proved. Using this lemma an algorithm, based on the work of Everett, and Brooks and Geoffrion, is developed. It determines an initial feasible solution if one exists, several intermediate solutions of which some may be feasible, and an upper bound on the optimal value of the objective function. Finally, an improvement algorithm is given that will locate the

optimal feasible solution. An example problem is presented to illustrate the algorithm as an application of discrete mathematical programming.

WA7.20. Linear Programming Applied to the Analysis of Variance of Designed Experiments, FRED L. CASHLER and BEN T. RHODES, JR.

This paper shows how a linear programming computer code can be used to obtain the sums of squares needed for analysis of variance in designed experiments. The advantage of this approach is that it can be used for any design. It is particularly useful for nonorthogonal designs, missing data and other problems which are difficult to handle with traditional analysis. The paper includes several examples from standard textbooks so this approach can be compared to other procedures.

WA7.21. Simple Procedure for Constructing Orthogonal Latin Squares Using Congruence Relations, MOHAMMED M. SHAMMA.

The procedure of constructing orthogonal latin squares has been varied in its methodology and complexity. This paper will give a simple and quick method of constructing at least two orthogonal latin squares of any odd order using a congruence relation which is a function of the order. This method will produce magic squares as a by-product. A one-to-one correspondence between magic squares of odd order and two orthogonal latin squares of the same order will be demonstrated.

WA8.1. Econometric Simulation in the Timber Industry, ROBERT M. CLINKSCALE, JR.

The model employs a stochastic sequential analysis process based on Markov chains. Merchantable wood volumes are projected based on assumptions regarding species, site class, regeneration and tending techniques, fire protection, harvesting techniques, etc. Projected wood volumes are assigned to primary industry product outputs. All parameters related to the growth simulation can be varied to test sensitivity of results. Direct benefits and costs are projected based on demand and supply assumptions and computed as present values. Indirect benefits and costs (e.g., environmental impacts) are considered. An investment evaluation algorithm computes present value of net benefits in terms of ratios, differences, or rates-of-return and optimizes total net benefits for a given level of expenditure.

WA8.2. Some Experimental Results Using Variance Reduction Techniques in Simulation, FRANK A. DUNN.

Computer simulations with large models frequently require large amounts of computer time and are quite costly to run. Various techniques have been proposed in the literature for reducing variance and/or length of run. Several of these techniques were tested, together with a method developed by the author, on three different models. The results of these experiments, a discussion of the author's method, and some discussion of the objectives of the experimenter are included in this paper.

WA8.3. A Mission-Oriented Reliability Model, ROBERT H. GRUHL.

In the design of complex systems, analysis of reliability, maintainability, and availability (R/M/A) of a system in its mission or operating environment is important. Using Markov chains, a reliability model has been developed to compute various R/M/A effectiveness measures of systems subject to restrictions and/or changes throughout a specified time interval. This paper analyzes the applicability and the limitations of a Markov chain model in determining the R/M/A effectiveness of a system over a given mission time. The model's efficiency in calculating effectiveness measures for the more common non-mission R/M/A problems will be compared with other reliability models.

WA8.4. Maximal Steady State Flow Characteristics for an Idealized Railway System, DIETRICH R. BERGMANN.

Railway systems are defined within this paper to include any system of guided

ground transport in which the spacing between two successive vehicles cannot be less than the following vehicle's stopping distance. Start-up conditions, spacing control alternatives, and mechanical aspects of vehicle design are delineated and applied in models which give maximal steady state flow and take the form of numerical techniques or, in some special cases, closed form expressions. The paper concludes with a discussion of how these theoretical developments can enhance the precision of contemporary modeling efforts for railway systems flow and secondly, facilitate the optimal design of advanced urban public transportation systems.

WA8.5. A Systems Model for Energy Management, JACK BYRD, JR. and R. DAVID HAYNES.

The recent crisis in our national energy supplies has stimulated the need for taking new approaches to our energy problem. A systems model has been developed which shows the interfaces in our national energy policies. As this model illustrates, it is imperative that future policies be viewed from the total systems concept. Using this model, energy decision makers can be aware of the influence of their decisions upon our national energy needs. At the same time, environmental policies, transportation investments, and other programs can be evaluated in light of the impact that these programs have upon the total energy system.

WA8.6. Measuring Prices in the Computer Time-Sharing Market, ROBERT T. FILEY.

The computer time-sharing industry has developed a complex and nominal pricing structure which makes price comparisons among vendors extremely difficult. Although effective prices are functions of the nominal prices, the nature of these functions is impossible to determine without substantial testing. This paper develops a methodology for the accurate measurement of effective prices and presents the results of a recent application of this methodology to six time-sharing services.

WA8.7. Optimal Service Policies for Solid Waste Treatment Facilities, HELMAN I. STERN.

The system investigated consists of a stochastic periodic stream of raw waste, a processing operation with controllable deterministic service rate and adequate storage capacity. The arrival stream is periodically interrupted and divided into alternating "on" and "off" intervals of fixed length. The processing facility is allowed to operate during the "off" interval. Superimposed on this system is a cost structure composed of processing and holding costs. A service rate rule that minimizes the infinite horizon discounted expected total cost is found. Since the optimal policy cannot be expressed explicitly, an approximate solution was obtained. An error bound on the optimal cost associated with this solution is exhibited.

WA8.8. Analysis of Management Decision Making In Information System Design, MICHAEL E. COHEN.

This paper describes an analysis of management decision making in the design of a public finance management information system. A methodology is developed to establish information requirements for selected decision categories (planning, control, and evaluation) for various levels of management in a city government. These requirements are then related to the current information system in the city to determine the adequacy of the system to support decision making. The results permit a determination of priorities for detailed systems design.

WA8.9. The Comparative Value of Artillery and Air Support in World War II, ROBERT MC QUIE.

A discriminant function was used to analyze division engagements of World War II. Changes in the mix of US and enemy weapons were related to the probability of a US success or failure in combat. The coefficients of the function provided an objective measure of the comparative values of Army, Navy and Air Force weapons. The change in

probability of success was estimated for each engagement with decreases in the amount of artillery or air support.

WA8.10. Dynamic Programming in the Allocation and Management of Graveyards, Q. A. M. M. YAHYA.

In cities around where fallow land is almost non-existent and where limited land can possibly be purchased at a very high rate, the city municipal authorities face a difficult situation in the allocation of graveyard spaces. The model under study takes the following realistic points into its framework; (1) A fraction of the population will always be willing to purchase the land for "permanent" graves at any price, and along with inflation in the country, such fraction of population tends to increase spirally; (2) The public who do not intend to go for "permanent" graveyard spaces are provided with "replaceable" spaces, replaceable after every 3, 5, 10, 15, years depending on various categories; (3) The population of the city is assumed to expand exponentially with time and the death rate is normal as ascertained from previous municipal statistics and death registers. Apparently, the policy of the municipal authorities must be a multi-stage decision policy, including the policy of new land purchase whose price goes up, say, by 25% every 5 years. In this preliminary study, it is shown how the dynamic programming approach can benefit the authorities.

WA8.11. Determining the N Most Vital Links in a Flow Network, S. H. LUBORE, H. D. RATLIFF, and G. T. SICILIA.

The n most vital links in a single commodity flow network is that set of n arcs whose removal results in the greatest reduction in the value of the maximal flow in the network between a source node and a sink node. Some new results concerning this problem are developed and a solution technique is suggested.

WA8.12. Contingency Planning at a Bank Holding Company, JOSEPH E. MICHINI.

The interaction time-sharing use of computer technology has permitted the development of a contingency planning system (CPS) at Marine Midland. CPS allows comprehensive higher level planning while exploiting the detailed knowledge available at the lower levels. CPS has the capability of transmitting to each of the basic responsibility centers operationally meaningful management directives, goals and expectations with a feedback system that displays the decisions, commitments, and efforts of these centers. Used in the framework of a planning situation, CPS can examine the impact of a set of interrelated policies, decisions and assumptions on a changing environment.

WA8.13. Computer Network Simulator, JOHN L. REDDING.

A model for a network of computers has been developed and a simulation program has been produced. The computer located at each node of the network is characterized by its multiprogramming capability, the amount of main storage available, the number of I/O channels available, and its job stream. The job stream is described by a set of probability distributions. The network itself is described by the node connections. The simulator facilitates the analysis of tradeoffs between centralized and distributed data bases, the study of network performance, and communication line and data bank utilization.

WA8.14. A Simplicial Method for Nonlinear Programming, AMILCAR S. GONÇALVES

Nonlinear Programming problems with linear constraints may be solved by direct methods such as the Reduced Gradient or Gradient Projection methods. However, these methods are not finite and their convergence to an optimal solution is only proved under further hypothesis. The algorithm constructed here to solve the problems is finite, and in the case of a linear objective reduces to the simplex method. If the objective is quadratic the resulting algorithm is similar to Beale's method for Quadratic Programming, but always avoids Beale's "free variables". It is proved to be a profitable computationally improvement of Beale and Van de Panne's algorithms.

WA8.15. Economic Model of a Two-Level Material Distribution System, WILLIAM SHELSON.

This paper describes the economic modelling of a two-level warehouse system using six significant cost elements. These elements relate to warehousing, procurement, transportation, handling, planning and shortage factors. The model, which includes optimization features, provides a quantitative comparison of alternative distribution strategies. One of the strategies considered is based on a very rapid delivery service and low shortage levels. The paper includes a description of this strategy and the results obtained from a real-world test of the strategy carried out over a full year.

WA8.16. Recreation System–Transportation System Interaction Cycle, RICHARD A. LADD.

Attention is focused on the total environment approach to recreation and transportation development. The interaction of recreation and transportation systems is presented as a cycle of altered benefits and requirements resulting from an "accessibility factor" and an "attraction factor." The role of improved transportation accessibility, generating reduced leisure experience benefits and increased pressure for expansion of recreation facilities, is examined along with the impact of improved recreation attraction on transportation usage and development requirements. Total environment recreation and transportation development requires the systematic integration of both attraction and accessibility factors.

WA8.17. A Markovian Model of Patient Flow in Comprehensive Health Care Projects, BJORN LARSEN.

Elements of care in the comprehensive health care cycle can be defined as a series of sequential steps in the process of delivery of health care. This process can be conveniently described and analyzed in terms of an absorbing Markov chain. The practical application of the model as an administrative tool for planning, organizing, directing, and supervising health care delivery is demonstrated through an empirical analysis based on data extracted from the Quarterly Summary Reports developed for the Children and Youth Comprehensive Health Care Services Delivery Program.

WA8.18. Theory and Application of End-Product Pipeline Problems, MARSHALL ROSE.

An important class of problems common to the military and large transportation companies requires allocation of resources between the total number of end products (some of which are operational, the remainder in a repair, or "pipeline" state) and the repair capability needed to periodically service them. This paper shows how to determine this allocation under several conditions. Further discussion considers the manner in which the system adjusts, through time, to changes in the end-product repair time. The model is then applied to the problem of finding the appropriate resource support levels for the Navy's F-4 aircraft.

WA8.19. A Coordinate Oriented Algorithm for the Traveling Salesman Problem, JOSEPH SIDNEY GREENE, SR. and A. K. RIGLER.

A new algorithm is developed which gives a good approximation to the solution using reasonable computer time and which will converge to the exact solution if allowed to continue. This algorithm is a branch and bound technique which utilizes the distance between cities in its bounding procedure. The bookkeeping scheme for the algorithm is such that only the partial solution along with those routes currently being checked need be retained in memory. The branching technique requires that only one row of the distance matrix be in memory at any time. Two new theorems are presented which play a major role in the development of the algorithm.

WA8.20. The Estimation of Probability Densities and Cumulatives for Computer Modeling, MELVIN O. BRAATEN and SHANTILAL JAIN.

An algorithm is developed which facilitates approximating empirical probability

functions with continuous parametric probability density functions and cumulatives. The algorithm develops estimators for several classical density functions such as the exponential, normal and beta, as well as estimators for generalized functions which permit fits to a broad class of empirical data. Measures of goodness of fit and a graphical display of the fit are presented to aid in the choice of the appropriate function.

WA8.21. Bayesian Control Policies for Stochastic Processes, PHILLIP L. CARTER.

In many production situations one is faced with the problem of controlling stochastic processes by making decisions based on samples of the output. One typically faces the alternatives of allowing the process to continue or of overhauling the process and returning it to the desired state. In addition to considering the immediate costs of each alternative, the decision maker also has to consider the consequences of his current decision on the future state of the process. The purpose of this paper is to show how optimal control policies for stochastic processes can be found using Bayesian decision theory and dynamic programming.

*WP2.1. Multiprogramming Models, DONALD P. GAVER.

The term "multiprogramming" refers to the successive processing, by high-speed central computing unit (CPU), of parts of several programs that are simultaneously in memory. Processing of one program proceeds until interruption (e.g., by page fault), at which time processing picks up on an alternate program. Models in terms of cyclic (partially non-Markovian) queues are discussed, particular attention is devoted to program through put. Approximations based on diffusion theory are introduced and evaluated.

*WP2.2. Optimal Modes of Multiprogramming, PETER J. DENNING.

Suppose one is given a cost function that describes the cost of running a paged program in a fixed work space under a given paging strategy. The cost of multiprogramming under a local strategy is given by a linear combination of the work-space costs, and under a global strategy by a suitable average over the partitions induced. A paging algorithm is optimal if it minimizes the cost function for one work space, and a partition is optimal if it minimizes the cost of a local paging strategy. The principle result states that, for an optimal algorithm there exists an optimal partition such that the cost of applying the optimal paging strategy locally is less than the cost of any paging strategy applied globally. Optimal partitions may be approximated by using the working set model.

*WP2.3. Processor-Sharing Queueing Models of Mixed Scheduling Disciplines for Time-Shared Systems, LEONARD KLEINROCK and R. R. MUNTZ.

Scheduling algorithms for time-shared computing facilities are considered in terms of a queueing theory model. The extremely useful limit of "processor-sharing" is adopted, wherein the quantum of service shrinks to zero, this approach greatly simplifies the problem. A class of algorithms is studied for which the scheduling discipline may change for a given job as a function of the amount of service received by that job. These multilevel disciplines form a natural extension to many of the disciplines previously considered.

Solved for is the average response time for jobs conditioned on their service requirement. Explicit solutions are given for the system M/G/1 in which levels may be first-come-first-served (FCFS), feedback (FB) or round-robin (RR) in any order.

*WP2.4. Routing in Computer Networks, H. FRANK and W. CHOU.

The problem of routing traffic in a system of computers is extremely complicated. Among the properties of a desirable flow pattern is low average time delay from message inception to arrival. In this paper, we discuss routing procedures for minimizing average time delay subject to a set of flow constraints. Both suboptimum and optimum routing procedures are presented and the sensitivity of the solutions with respect to the estimation of the required traffic is discussed.

*WP4.1. Average Cost Criterion in Markov Decision Processes, M. J. MAGAZINE and PRAGATI SEHGAL.

A number of authors have recently obtained results concerning the analysis of Markov decision processes with average cost criteria. This survey draws together and unifies these results. Emphasis is placed on the existence of optimal policies, rather than their computation. Discrete-time, continuous-time and semi-Markov processes are considered.

*WP4.2. Lyapunov Functions for Markovian Decision Processes, PAUL J. SCHWEITZER.

This paper shows that the method of successive approximations proposed by White for solving undiscounted Markovian decision processes (and its generalizations to discounted and semi-Markov processes) is a finite-difference approximation to a set of differential equations. Convergence of both the discrete and continuous formulations is proved by the method of Lyapunov functions, which shows that the equations are asymptotically stable with a unique fixed point.

The Lyapunov functions measure the degree to which any given value-vector fails to satisfy the functional equations of dynamic programming. The iterative schemes drive the Lyapunov function monotonically to zero, assuring convergence. In addition, the size of the Lyapunov function is an essentially linear measure of the deviation of the current value-vector from optimality, and permits an estimate of the latter.

*WP4.3. Maximal Average-Reward Policies for a Class of Semi-Markov Decision Processes with Arbitrary State and Action Space, STEVEN A. LIPPMAN.

We consider the problem of maximizing the long-run average (also the long-run average expected) reward per unit time in a Semi-Markov Decision Process with arbitrary state and action space. Our main result asserts that we need only consider the set of stationary policies in that for each $\epsilon>0$ there is a stationary policy which is ϵ-optimal. This result is derived under the assumptions that (roughly) (i) expected rewards and expected transition times are uniformly bounded over all states and actions, and that (ii) there is a state 0 such that the mean recurrence time from state 0 to state 0 is uniformly bounded over all policies. The existence of an optimal stationary policy is established under the additional assumption of countable state and finite action space. Extensions and applications of these results to queueing reward systems will be given.

*WP4.4. Markov Renewal Programs with Unknown Parameters, B. L. FOX and J. E. ROLPH.

We consider denumerable-state, denumerable-action Markov renewal programs with unknown parameters. Under suitable conditions, we find a (nonstationary) policy that maximizes expected reward per unit time.

WP4.5. Deterministic Discrete Dynamic Programming with Discount Factor Greater than One, YVO DIRICKX.

The paper analyzes the deterministic version of the discrete dynamic programming model where the discount factor for future rewards is greater than one. A meaningful solution concept is introduced and the class of optimal policies is studied from two different viewpoints. On the one hand, asymptotic analysis is used. This approach yields turnpike theorems and 'almost stationary' optimal policies that are calculated by a finite algorithm based on linear programming. The second approach, which is a strict infinite horizon analysis, yields optimal policies that are generally nonstationary and that are calculated by a finite algorithm. An example is presented. Applications and extensions are discussed.

WP4.6. The Optimal Admission Policy to a Multiserver Queue with Finite Horizon, HAMILTON EMMONS.

An M/M/s queueing system with a simple cost structure is considered, under the assumption that the system will close in a finite time after which any remaining

customers will require extra overtime service costs. We determine the optimal policy for admitting customers to the queue, as a function of the time, t, to closing and the current queue length, i. It is shown to have the form: admit if and only if i lies in some interval $[a(t), b(t)]$. These bounds are specified, and it is shown under what conditions $a(t)$ is identically zero (a control limit rule) or $b(t)$ is identically infinity (an inverse control limit rule).

WP4.7. A Generalized Recursive Algorithm for a Class of Nonstationary Regeneration (Scheduling) Problems, FRED GLOVER and THEODORE D. KLASTORIN.

Recent efforts in the field of dynamic programming have explored the feasibility of solving certain classes of integer programming problems by recursive algorithms. Special recursive algorithms have been shown to be particularly effective for problems possessing a 0–1 attribute matrix displaying the "adjacency property" (Glover) and/or the "nesting property." (Ignall and Veinott)

This paper extends the class of problem structures that have been shown amenable to recursive exploitation by providing an efficient dynamic programming approach for a general transportation scheduling problem. In particular, we provide alternative formulations for the scheduling problem and show how the most general of these formulations can readily be solved vis a vis recursive techniques.

WP4.8. On A Two-Dimensional Resource Allocation Problem, JONATHAN S. YORMARK and NORMAN R. BAKER.

A two dimensional resource allocation problem is considered; for example, allocation over activities and time periods. The independence and separability of returns for a given activity-time period pair is assumed. The form of the model is essentially a generalization of a nonlinear capacitated transportation problem. Lagrange multipliers are introduced and the Lagrangian is shown to decompose into a sequence of bounded-variable nonlinear knapsack problems, amenable to solution by dynamic programming. Several results are proven for piecewise convex return functions including (1) the piecewise convexity of the optimal payoff (knapsack) function and (2) the structure of the admissible policies. The result (1) accelerates the calculation of the knapsack functions. The result (2) leads to (3) a closed form solution under the assumption of equal allocation bounds for an activity across time.

*WP5.1. An Application of Vehicle Scheduling to School Transportation, WILLIAM L. CAUDLE.

This paper reports on an application of computer technology to a significant school administration problem: the safe and economic transportation of students between home and school. After an historical introduction of progress in computer-assisted routing, the basic approach in this application is outlined, the resulting system is described, and all phases of the project from data collection through route implementation are presented Particular emphasis is placed on problems, technical, administrative, and human, which are encountered in any such application.

*WP5.2. A Dynamic Vehicle Merging Control System, H. L. GROGINSKY.

An experimental computer based freeway ramp control system has been designed, installed and tested under sponsorship of the U. S. Department of Transportation with the cooperation of Massachusetts Department of Public Works. This system regulates the flow of traffic onto the freeway and provides advisory control for the ramp vehicle driver enabling him to effect the merge more expeditiously. The paper discusses some of the factors leading to the choice of the various techniques used in the system and the results of a 6 week interval in which the system was tested in Massachusetts.

*WP5.3. Technological Innovation in Urban Transportation–The Role of the Federal Government, ROBERT A. HEMMES.

The Urban Mass Transportation Administration of the U.S. Department of

Transportation has a program of research, development and demonstration projects to test and evaluate new concepts and systems in urban transportation. One of the goals is to translate the results of analytical and theoretical research to practical urban applications. Results of past and present work will be reviewed and plans for the future will be outlined. Emphasis will be placed on the impact of the recently passed Urban Mass Transportation Assistance Act of 1970.

*WP5.4. Implementation of Computer Algorithms for the Dial-A-Bus System, NIGEL WILSON and JOSEPH SUSSMAN.

This paper reports on the design, development and initial testing of an innovative transportation system called Dial-A-Bus. Dial-A-Bus is designed to provide door-to-door service at a low cost to the user. The system is basically a large-scale shared-taxi operation with a computer performing the control function. This computer monitors the state of demand and assigns vehicles to new requests so as to minimize passenger service times. This paper traces the evolution from initial design of assignment and travel time prediction techniques to implementation strategies considering cost and speed of computation as well as vehicle routing performance.

*WP5.5 Monitor-CTA—An Automatic Vehicle Monitoring System, RALPH W. TRACY and WILLIAM M. BORMAN.

During the past several years considerable research has been done regarding automatic vehicle monitoring systems. The Chicago Transit Authority has recently installed the first such system to be used in urban public transportation. Monitor-CTA is a command and control system which includes the following features. 1) A constant monitor of a bus fleet automatically comparing the adherence of the bus to a prepared schedule with the ability of dynamic rescheduling; 2) provide instant identification of an operator and vehicle location in the event of an emergency; 3) provide two-way voice communication and 4) supply a constant flow of management information.

S1. A Mathematical Model of a Plant Leaf, JAMIL AHMED.

Interactions of growing plans with their environment are very complex which make the development of an integrated mathematical model to optimize their performance a very difficult one. Leaves, however, play a very important role in the growth of plants. This paper deals with the leaves as a sub-system of the whole plant system. Mass and energy conservation equations are combined with the equations of enzyme kinetics in such a way that they link various leaf parameters into a complete model on which the effects of environment can be simulated and the conditions for plant growth may be optimized.

S2. Gradient Projection Algorithm Applied to a Least Time Problem in Physics, M. AFTAB ALAM.

Gradient projection algorithm has been applied to the problem of minimizing travel time between two fixed points separated by a sequence of parallel layers. The speed of travel is different and varies linearly along each layer. An initial solution is obtained by travelling along the straight ray which connects the end points. The ray gers curved with subsequent iterations resulting in a reduced travel time. For thin layers the optimal ray satisfies Snell's Law. Numerical results from an acoustical model are described.

S3. A New Theory of Optimal Investment, DONALD C. AUCAMP.

A new investment objective function is offered which determines optimal portfolios when the joint probability distributions of the returns are known. The best portfolio is shown to be not only optimal from the standpoint of the assumed objective function, but also from the standpoint of realized monetary profits over the long run. That is, superior actual dollar performance is achieved, with probability one, over any other "significantly different" strategy. In particular, the optimal strategy is favorably compared with the

maximum–expected–profit–strategy. The theory is also applicable to many other problem areas involving decision making under risk.

S4. An Analytical Theory of Risk Versus Return, DONALD C. AUCAMP.

Two theorems are developed which can be used in determining the best trade-offs between portfolio return (mean) and risk (standard deviation). These theorems are applied to several examples of fundamental interest in the investment field and are also applicable to other problem areas involving risk-return trade-offs.

S5. Multiple Deferred State Sampling with Tightened Conditional Acceptance, R. C. BAKER.

This paper is concerned with attribute sampling inspection procedures in which the decision criteria for each lot dictates one of three dispositions; (1) accept the lot, (2) reject the lot, or (3) defer the decision until the disposition of future lots are known. A lot placed in a deferred state results in a tightened acceptance criteria for a specified number of future lots. This type of procedure eliminates the deferred queue problem associated with deferred state and multiple deferred state sampling procedures. Deferred state sampling procedures also provide highly desirable operating characteristic curves.

S6. Sequential Test Procedure with Delayed Observations, RAU C. CHANG.

Given a general decision problem, a finite sample is taken. However, the outcomes of the sample are not immediately available, i.e., there is a random time delay between the taking of each observation and the obtaining of its outcome. Assuming there is a cost associated with time, the paper explores an optimal testing procedure with a restriction that the decision has to be made before a certain time limit. In other words, the paper studies the optimal sample size, optimal stopping rule and optimal terminal decision with the optimality being in the sense that the total expected cost is minimized.

S7. Stochastic Single Commodity Network Flow, J. W. CRAWFORD.

The stochastic single commodity network flow problem is represented as a continuous-time, discrete-state Markov decision process. In the problem formulation, the unit flow occurrences and flow durations are both treated as stochastic processes; an example problem is treated in detail to illustrate the formulation of the problem and the flow control. A detailed analysis for a case with specific forms for the flow occurrence and flow duration distributions is given. The nature of the generalization of these results for the solution of a class of stochastic network flows is discussed, as is a simplified method for calculating the expected flow value.

S8. Formulation of the Dynamic Deterministic Inventory Model as a Branch and Bound Programming Problem, RICHARD H. DEANE.

This paper presents the dynamic deterministic inventory model as a combinatorial programming application which can be solved with "branch and bound" routines. The tree structure of the problem is explained along with the procedure for generating branches and computing successive bounds for each node. The classical approach to the inventory problem is through dynamic programming. The paper then illustrates how the branch and bound approach can reduce computations by eliminating certain routes from consideration early in the search.

S9. Aircraft Rearming and Refueling Simulation Model, ROBERT D. DROWLEY and DAVID O. TROTTER.

This report presents a discussion of the simulation involved in developing a model of an Air Force base under combat conditions. This project was the result of an instructor's need for a computer program which would yield meaningful results when varying input parameters were used by his students. The report begins with a discussion of the problem and a comparison of this project with other simulations on similar topics. From this point, it develops the model, including an explanation of the use of SIMULA in

the program. Finally, the report ends with the results and how the simulation is used by the student as well as its future uses. Thus far, the model has worked quite successfully, but there remains much room for expansion in the framework which has been laid down.

S.10. Interpreting Accident Statistics, JOSEPH FERREIRA, JR.

Statistics developed from driver accident data are often used to support the argument that a small proportion of drivers account for a large proportion of the accidents and that removing this small proportion of drivers from the road would substantially reduce the total number of accidents. This paper investigates the accuracy of such inferences. Accident statistics developed from six-year driver records of 7,800 California drivers are studied and the results obtained from the actual data are compared with those predicted by compound Poisson models for driver accident involvement that assume specific variations in accident likelihood among drivers.

S11. Final Report on the Simulation of the Production Run of the Magic Tee at Microwave Development Laboratory, ALAN J. GOLDBERG.

This report informs how a computer model of the production of the magic tee, a radarscope component, was formulated. Computer simulation in Fortran was used to model the production run so it approximated reality. The analysis focuses on developing a model of the present production setup.

S12. Nonlinear Optimization with Upper and Lower Bounds, V. E. HUCKFELDT.

Many nonlinear programming problems containing only upper and lower bounds are currently solved as unconstrained problems using transformation, or penalty methods of optimization. In this paper it is shown that (1) Goldfarb's conjugate gradient algorithm can be simplified for NLP problems containing only upper and lower bounds, (2) the simplified algorithm requires less computer storage, less time per iteration, and reduces errors, and (3) the simplified algorithm is superior to transformation, or penalty methods when tested on published nonlinear test problems. A FORTRAN code for the nonlinear algorithm for upper and lower bounds, including complete documentation, is presented.

S13. A Dynamic Resources Planning Model with Technological and Resource Changes, L. L. JAYARAMAN.

Secular technological change and increase in the cost of the resources make resources planning vital within organizations. In Corporate planning, the effect of these changes have seldom been explicitly taken into account resulting in lack of adequate *development* and utilization of resources and choice of suboptimal technology based on short-term criteria. A dynamic model of resources planning in the context of continuing technological change and changing resource attributes has been proposed. The output of the model is the *optimal time-path of resource development and utilization* and the technology thereof. An example illustrates the working of the model.

S14. A Branch and Bound Method for the Fixed Change Transportation Problem, MARY W. COOPER.

An exact branch and bound algorithm is presented for the fixed charge transportation problem. An approximate method is also given with computational results. The fixed charge transportation problem is embedded in a larger problem to which a branch and bound algorithm is applied. The algorithm describes a path through the vertices of the constraint set of the larger problem. The path terminates in the optimal solution to the fixed charge transportation problem.

S15. Time Sharing with an Explicit Priority Queuing Discipline, CYRUS RUSTAM MEHTA.

This paper is a mathematical analysis of a round-robin computer time sharing system which is characterized by homogeneous Poisson arrivals, exponentially distributed service times and an ordered priority queue. Each new arrival buys a position in this queue by offering a non-negative bribe to the manager of the computer facility.

The system is modelled as a continuous time stochastic process and is analyzed by the method of imbedded Markov chains. Relevent queuing statistics are identified and derived in terms of system parameters. The sensitivity of these results to changes in key system parameters is investigated through numerical examples. Finally under the assumption that the manager of the computer facility wishes to maximize the expected revenue per unit time accruing from bribes, an optimization problem is formulated and solved with two of the system parameters as decision variables.

S16. CAINS-A Computer Aided Instruction System, L. J. MILLER.

The purpose of this paper is to describe a design research project in computer aided instruction. Within the general guidelines of computer aided instruction, this paper deals with one particular system implemented at the United States Air Force Academy. The system design was constructed with much thought given towards expansion of the system. The topics this paper deals with are as follows: a) the design of the data files, b) the revolutionary system of questioning and learning, c) the options open to any using organization, d) the overall theory and design of the system, and e) the implemented version of the system. This paper was written with the hope that experts and novices alike may use this system as a new approach to the area of CAI.

S17. The Generalized Lagrange Multiplier Technique Applied to an Inventory Problem, S. C. MOORE.

The problem of determining initial stockage quantities for a multiproduct inventory of repairable items is considered. The inventory policy is $(s-1, s)$ for each item, and the total investment limit is known approximately. A brief stochastic description of inventory demand and replenishment permits formulation of alternative objective functions for an integer nonlinear programming problem. Primary emphasis is given to minimizing total expected backorders. This problem is easily solved with an application of the Generalized Lagrange Multiplier technique, and in light of this formulation the problem can be modified by adding constraints or substituting objective functions. Computational aspects are considered whenever possible.

S18. Sequential Decisions Over a Finite Collection of Mutually Independent Markov Chains, STEVEN NAHMIAS.

This paper introduces the concept of random movements among independent Markov chains and deals specifically with the case where these movements are defined by a decision process. The object of the analysis is to make a decision at each stage (which constitutes choosing one of the chains) to minimize a specified cost criterion. Previous related work is examined and hypothetical applications are given. By introducing sufficient statistics the problem is restructured as a Markov decision process and the existing knowledge in that area is exploited. In addition some specialized results and computations are given.

S19. Go-Stop; *G*lobal *O*ptima by a *S*equential *T*esting *O*ptimization *P*rocedure, THEODORE C. ROBBINS.

Effective unconstrained optimization algorithms are important of themselves and since the solution of constrained mathematical programs often involves solving sequences of unconstrained optimization problems. This paper describes a procedure for localizing the global optima of multivariate objective functions. From randomly chosen initial points, locally optimum solutions are identified by applying a modification of Zangwill's CSM-CD algorithm to polynomial approximations of the function. Under the null

hypothesis that all local optima have been found, sequential testing is employed to terminate the search for optima when the probability of making a type II error falls below a pre-specified level.

S20. The Use of Experimental Design in the Control of Continuous Processes, CASS SCHICHTLE.

This paper examines the possibility of using the Completely Random Two-way Classification Experimental Design Model to control continuous processes. The term "continuous process" as used herein refers to those daily production line functions required to manufacture a product given all the needed and previously inspected raw materials. The model is developed and the theory of control charts based upon it is purposed. Probability of acceptance or operating characteristic curves are plotted based upon twenty-two hundred experiments ran on a computer. Finally, an example using the control charts is presented. The success of this technique has spurred further research into more sophisticated experimental designs and the results to date appear very exciting.

S21. Optimization of a Production Flow Model, JAY D. SHERMAN.

A production system is modeled as a flow network. Different quality control and equipment selection policies at each stage of the system interact to result in varying flow rates and net return. A dynamic programming algorithm is used to optimize net return of the production system under differing conditions of demand. Systems of both serial and non-serial stages are optimized. Numerical examples are given.

S22. Terminal City Defense, KENNETH C. SHUMATE.

This paper presents a ballistic missile defense allocation model for the terminal defense of cities of varied value. The model is based on a "worst case" analysis for the defense. Defensive missiles have a probability of interception, offensive reentry vehicles are perfect, and the offense knows both the defensive allocation and firing doctrine. The area defended by a single interceptor farm is considered to be a point target and can be defended by no other interceptors. For any value of the offensive payoff in expected value per reentry vehicle, the model determines the least cost minmax allocation and firing doctrine. Game theoretic techniques for further reducing the cost when the offense does not know the defense firing doctrine are discussed and illustrated.

S23. The Need for a Fourth Jetport Serving the New York Metroplex—A Systems Study, SIDNEY J. STERLING.

A considerable effort has been expended by both public and private institutions within recent years to justify why or why not a fourth jetport should be constructed to serve the New York Metropolitan Area. This effort which has been significant in the collection of data has also been tantamount in the amounts of funds and political jocularly expended. This paper attempts to crystalize these diverse elements into a systems approach to the problem by giving objective weights to the data, socioeconomic factors and political inferences. A mathematical model is derived and subsequent analysis follows.

S24. Approximations to Optimal Policies in a Stationary Multicommodity Inventory Model with Set-Up Cost, WILLIAM DENNIS WACKER.

A stationary multicommodity inventory model with periodic review and continuous demand is studied when we follow a stationary m-dimensional (s, S) policy. The set-up cost is a positive constant while the holding, penalty and unit purchase costs are linear. For large values of the set-up and penalty costs, we use asymptotic expansions to simplify the equations determining the approximately optimal values of the policy parameters to the point where any further simplification appears to depend on the probability distribution that the demand obeys. Finally, we restrict our attention to the special case where the demand obeys the bivariate exponential probability law.

WP7.1. Alternative Generation Using Mixed Integer Programming, DAVID W. ALDRICH.

The purpose of this paper is to summarize our experiences with several mixed integer codes used for investment planning at Weyerhaeuser Company. In order to place these results in the proper perspective, the alternative generation model will be described in addition to a review of the general planning process. Emphasis is placed upon two mixed integer systems: a branch and bound code developed by Sema and a decomposition code developed by Bonner and Moore.

WP7.2. Using Branch Classification in Forecasting Bank Volume, BARR ROSENBERG and RONALD J. LANSTEIN.

Wells Fargo Bank has annually prepared goals for accounts at the branch level. Heretofore branch managers initially formulated branch goals. However, great difficulty was encountered in constructively revising these when their sum was inconsistent with senior management's aggregate goals. The Bank's Management Science Department undertook to develop preliminary branch allocations consistent with aggregate goals, using estimates of expected and potential growth rates for each account in each branch. The estimation problem was decomposed into three components: overall branch activity, overall account volume, and the effects of branch character on the distribution of activity across accounts. The latter were estimated using branch classifications developed in cooperation with operating personnel.

WP7.3. Analysis of CPU Dispatching Rules for Batch Multiprogramming Computer Systems, D. L. BOYD and D. L. EPLEY.

The effects of CPU task dispatching rules on batch-processing multiprogramming computer system performance is determined by formulation and analysis of a multiple resource model. System resources represented in the model include CPU time, I/O channel time and a set of static resources such as I/O devices, nonshareable data sets, etc. Three common dispatching rules, FCFS, round-robin and foreground-background queues, are studied. Relative performance under these rules is shown to depend upon the degree of balance between CPU and I/O system capabilities and average number of jobs in execution. The latter parameter is dependent upon static resource demands since the model allows new jobs to be blocked by jobs in execution, i.e., those in the CPU and I/O stages, because of conflicts in static resource demands.

WP7.4. Process Optimization for Water Pollution Control, CHIA SHUN SHIH, DUANE J. WRAY, G. A. ELLIFF, and W. L. MEIER, JR.

Water pollution control has become the most concerned topic because of its ever-increasing qualitative deterioration and quantitative demand. The mathematical programming techniques applied on water pollution control process optimization is thus a challenging task in view of the urgent need and the state of art for its development. Treating the individual pollution control plant as specific microscale unit, the system may be optimized based on two-point boundary problems in mathematical programming. Each unit process may be modeled according to its unique performance functions and water quality improvement goals. The potential gain of various mathematical programming techniques adapted for the economic optimization of different unit processes have been explored and discussed.

WP7.5. Scientific Design of a Hospital Training System, ROSALIE KASABA, BECKY ABATO, and CARL E. HOPKINS.

A medium sized hospital attempted a scientific attack on the problem of individualized training of personnel. The concept was that the total operation could be decomposed into job components with primary relationship to the function, not to the position. Work in four phases included: identification and specification of job components, baseline performance measures criterion for desired level on each component; a value model and training allocation scheme; a pilot training program to meet speci-

fications. Each employee gets only the training he needs and simultaneous training of all having same needs is provided. Problems encountered are discussed.

WP7.6. Markov Decision Models in the Design of Structural Systems for Repeated Sequences of Random Loading, ERIK H. VANMARCKE.

This paper proposed a method based on continuous-time Markov chains and Markov decision theory to describe the behavior and evaluate the performance of structural systems subjected to randomly occurring sequences and combinations of loading and environmental conditions (hurricanes, earthquakes, floods, etc.). In the first part, the conditions are stated under which homogeneous Markov chain analysis, in terms of expected transition probabilities, is applicable. In the second part, examples are given of the use of the decision model (both the discounted and undiscounted cases) in defining and evaluating alternative designs and maintenance policies.

WP7.7. A Monte Carlo Simulation for Decision Tree Analysis, JERRY B. WILLIAMS and JAMES C. GOODWIN.

A Monte Carlo simulation for a type of decision tree analysis is described. This computer model, in use by the Strategy Planning staff in The Boeing Company, Aerospace Group, provides a means of evaluating strategies regarding allocation of resources to new business activities. Methodology was developed for analysis of sets of decision trees with interdependency between events on different trees. The interdependencies are defined by Boolean logical expressions and evaluated by utilizing an interpreter. Utilizing this methodology one can analyze a collection of interrelated programs without combining all program trees into an unmanageable form.

WP7.8. Solution of Mixed Zero-One Linear Programs by Ranking the Extreme Points, HAMDY A. TAHA.

An algorithm is developed for solving mixed (or pure) zero-one linear program based on the simple idea that the optimal solution must occur at an extreme point of the solution space provided, of course, that each constrained variable is limited to the zero-one range. Starting with the simplex method solution, Kutta Murty's procedure for ranking extreme points is used to locate the optimum integer solution. Procedures for generating bounds on the value of the objective function are provided. Preliminary experience indicates that the new algorithm is computationally feasible.

WP7.9. A Scoring Model Replacement for L. P., ISADORE M. KLAHR and J. V. POOLA.

In optimizing problems dealing with a m x n (m rows, n columns) matrix, several techniques exist to solve them. For example, if $n < m$ then mathematical programming techniques such as linear programming or non linear programming can be applied. However, in the special case when variable $m = 1$ the solution contains at most one nonzero. When the solution is known to contain p (for $n < p < m$) variables, this paper proposes a method of generating such a solution in a finite number of steps. It also gives the details of a computer program developed for solving such problems. A practical situation where this technique is applicable to advertising media selection is included.

WP7.10. Economic Capacity Planning for Variable Demand, CARL B. ESTES.

This study presents models relating the decision variable to the random variable of future demand, with two general classes of costs applicable and related to the magnitude of the decision variable. Also, acting as a variable in the model is a restriction on the time allowed to meet a unit of demand.

Both discrete and continuous cases are covered and decision rules are developed based upon an expected cost criteria.

An application of the model would be in the determination of a capacity level, given regular and premium rates and stated guidelines of the time allowed (maximum) to meet demand.

WP7.11. Empirically Derived Inventory Decision-Making Models: Their Uses and Economic Consequences, STANLEY T. HARDY.

Although there are many rational economic models prescribing optimal or suboptimal buying behavior with respect to inventory replenishment and buffer stocks, many industrial buyers and inventory control managers appear to ignore them. Instead, these buyers and managers seem to be more responsive to organizational elements rather than the economic elements of the above models. This author constructed some of the decision-making models actually in use. These empirical models then were compared with some of the rational economic models previously described and the economic consequences for the use of these empirical models were calculated.

WP7.12. A Lambda-Form for Nonseparable Programming, PHILIP B. ZWART.

Piecewise linear functions in n-space are developed in terms of n-simplexes (which correspond to subintervals in the one dimensional case). This permits piecewise linear approximations to functions of n-variables. The resulting piecewise linear constrained optimization problem can be solved by a method which is a generalization of the lambda-form of separable programming. The standard results of separable programming carry over, e.g. 1) a local optimum is found by use of simplex method with restricted basis entry, 2) a bound on the global optimum is easily obtained.

WP7.13. A Branch and Double-Bound Algorithm for the Multi-Period Capital Budgeting Problem, F. OCHOA-ROSSO.

The problem of optimally allocating fixed capital budgets for various time periods among a finite set of competing proposals is referred to as the multi-period capital budgeting problem. This paper considers the problem of selecting the optimal combination of independent projects requiring capital outlays in several time periods. The problem is formulated as a maximum flow problem on a single-source single-sink capacitated network. A branch and bound algorithm permits the generating of an upper and lower bound at each step of the computation, furthermore, the solution of each linear programming problem may be obtained by simple inspection. A numerical example and substantial computational experience is given.

WP7.14. A Heuristic Algorithm for the Vehicle Dispatch Problem, B. E. GILLETT and LELAND R. MILLER.

A heuristic algorithm, called the sweep algorithm, is developed for the vehicle dispatch problem with distance and load constraints for each vehicle. The locations for a route are determined according to the polar coordinate angle for each location and an iterative procedure is used to improve the total distance for the route. A mathematical development and a step procedure for the algorithm is given. The solutions for this algorithm are compared with solutions from other vehicle dispatch algorithms, and the sweep algorithm is found to give better results for almost every problem. Various modifications are also presented for the algorithm.

WP7.15. One-Machine Deterministic Job-Shop Scheduling with Precedence Relations and Deferral Costs, JEFFREY B. SIDNEY.

An n-job, one-machine job-shop is considered. Associated with each job is its processing time and its deferral cost per unit of time until completion. All jobs arrive simultaneously, and the machine is continuously available until completion of all jobs. A general precedence relation (any partial order) defined on the set of jobs must be respected in ordering the jobs. The objective is to find that permutation of the jobs which minimizes the sum of the deferral costs.

A decomposition theorem describing the optimal order is developed, from which several old algorithms and a few new ones are derived.

WP7.16. An Analysis of Disruption Costs in Ship Construction (or The Case of the Missing Manhours), MILIND M. LELE.

Long lead times and changing requirements have made extensive design changes a common feature of ship construction. The cost of resultant disruptions have led to considerable controversy and litigation. A preliminary analysis of such disruption costs is presented which uses a stepwise multiple regression model to evaluate the cost impact of disruption. Some preliminary statistical evidence is given of the relationship between selected technical and schedule parameters of several dozen significant work packages and the associated cost impact of disruptions in those packages. These preliminary results are extended to the more general case of multiple ship contracts; this identifies the "cascading" effect of lead ship disruptions. Finally, some implications for ship design and construction methods are examined.

WP7.17. Generalized Jet-Select Policies Via Linear Programming, ROBERT C. FRESE.

Maneuvers required to control the translational and/or rotational orientation of a space vehicle are performed by a set of small jets referred to as the Reaction Control System. The economic premiums placed on fuel use and weight for long missions, in particular, suggest the development of a jet-select logic which minimizes fuel expenditures. Linear programming is shown to be an appropriate model for such a problem, and results of a computer program which prescribes maneuvers for several current and future vehicle configurations are presented. The routine is considered for use as (1) an on-board program for real-time use, and (2) a criterion to evaluate alternative selection logics.

WP7.18. Parametric Linear Programming Analysis of State Aid Plans to Non-Public Schools, EDWIN L. HULLANDER.

The expanding requirements and growing cost of operating an educational system has forced many non-public schools to seek state aid or terminate their programs. The basis for such state support should be based on an optimal allocation of public school resources. This paper presents a parametric linear programming model for the determination of the economic impact of providing educational services to non-public students. Of interest is the Lagragian formulation of constraints involving subjective range of educational quality. The model illustrates the variation in the cost-benefit relationships of various stratas of student enrollment.

WP7.19. Optimal Capacity Expansion of Pump Station Facilities, JACK H. M. FERGUSON and P. A. JENSEN.

A computer model was developed to determine the minimum present value cost policy for expanding the production of a facility over time. The installation time, size, and number of components are optimally selected in the policy obtained. Solution restrictions include: (1) meeting all demands, (2) maintaining a minimum percentage of a given component type, (3) adding only components for available facility space, and (4) selecting structure construction staging. Spare components to be installed are considered. Computational results for dense constraint matrices, 70 variables and integer decisions are discussed.

WP7.20. Toward the Stratification and Clustering of Metropolitan Areas, THOMAS F. GOLOB, EUGENE T. CANTY and RICHARD L. GUSTAFSON.

The analysis of urban problems and the evaluation of the impacts of new urban systems through use of individual case studies poses the problem of extension of case study results to more than 200 diverse metropolitan areas. This paper describes a technique to cluster metropolitan areas into relatively homogeneous groups. The technique involves the systematic application of multivariate statistical tools, including multiple regression, factor analysis and cluster analysis, to an extensive data base of measurements on all metropolitan areas. Application of this process in the identification

of representative areas for the case study of new urban transportation systems is presented.

WP8.1. An Approximate Method for Generating Random Variables, JOHN S. RAMBERG and BRUCE M. SCHMEISER.

A method for generating values of continuous random variables, which is relatively fast, requires essentially no computer memory and is easy to use, is given. The method, which requires a source of uniformly distributed random numbers, is based on the inverse distribution function of a generalization of Tukey's lambda distribution. Since this distribution can be adjusted to closely approximate many continuous distributions, including the normal and the gamma, the algorithm should be useful to simulation practitioners.

WP8.2. Associative Processors in the Solution of Network Problems, VINCENT A. ORLANDO and P. BRUCE BERRA.

An Associative Processor is a highly parallel computer in which data are content addressable by field. Logical and arithmetic operations can be performed simultaneously on all data words. Classical network problems exhibit a naturally associative data structure. This paper examines the impact of the Associative Processor on the solution of these problems. Specific areas investigated include minimum path, maximum flow and cost flow.

WP8.3. A Quantitative Method for Measuring the Value of Research and Development, MOHAMED E. TAYMOUR.

A regression model relating yearly R&D expenditures to company's sales has been developed and applied to actual data from an industrial firm. After adjusting the data for inflation and normal economic growth, the model was used to determine the time lag between changes in R&D expenditures and corresponding changes in sales. The marginal expected returns from increases in the R&D efforts were also computed. Results showed strong correlation between R&D and sales. An important advantage of the model is its ability to account for fall out effects of R&D that are difficult to detect otherwise.

WP8.4. Status Concept of Program Evaluation (SCOPE)—Designed for a Regional Medical Program, DON J. TRANTOW.

Barriers to evaluation of multi-component health programs include lack of specific goal statements and measurement criteria, and apathy deriving from misunderstanding of evaluation. Additional problems arise from diversities of health problem categories and geographic differences in needs and resources The prototypic evaluation strategy of the Georgia Regional Medical Program uses an approach designed to overcome these barriers: Status Concept of Program Evaluation (SCOPE). SCOPE provides "slice of time" data pictures of the problem attacked by each project, the current plan of action, ongoing performance, and impact tc date. Reports identify changes between times t and provide comparisons among similar projects.

WP8.5. The Use of the Antithetic in Simulations of Financial Systems, J. W. COLIN.

Computer simulation experiments of financial situations are becoming a commonly employed tool for descriptive quantitative analysis by both industry and banks. However, no statistical analysis has been presented to adequately analyze the results of an individual experiment.

The importance of accuracy in financial simulations of balance sheet and cash flow systems is such that a satisfactory method of dealing with time dependent data must be found. This paper proposes the use of the Antithetic as a variance reducing technique for these simulations. The theory of Antithetic sampling is based upon experimental designs which are negatively correlated to the original experiment.

WP8.6. A Method for Identifying Optimal Choices in the Development of Educational Media Systems, ALAN P. WOODRUFF.

The high investment associated with large scale development of media-based instruction systems requires that hardware system acquisition and software development strategy be optimized on the basis of a cost-benefit analysis which takes into account future systems development options. The model presented in this paper develops a mathematical description of the problem of allocating resources to different mixes of hardware systems. This descriptive model treats variable patterns of demand for different media-based systems and also system characteristics which allow for synergistic coupling of hardware components.

WP8.7. QUEST for Information, S. H. STRAUSS.

This paper describes QUEST, a generalized file management system. Important features discussed are the state-of-the-art on-line database definition and report formatting capabilities. A database is defined in a conversational mode at a CRT Display where the user answers questions regarding the files, fields (with editing criteria) and input data formats. Census data is analyzed as an example of its capability to input bulk data from any source and extract only that data of value to decision makers. Other features discussed are the system's user operations log which allows an evaluator to collect service time data for queuing analysis; the on-line query and update; and the computer aided instruction capabilities. QUEST has been developed for the U.S. Navy at the Fleet Computer Programming Center, Pacific, in San Diego.

WP8.8. Conflict in a Group Binary Decision, G. A. WHITMORE.

Group decision making and game - theoretic features of majority rule have been studied extensively from various points of view. This paper studies the nature of conflict in one type of situation where a group of individuals must choose between two courses of action by majority vote. The conditions for existence of a core are described and several examples of the game found in economic, social, and political situations are presented.

WP8.9. The Multicommodity Network Flow Model Revised to Include Vehicle Per Time Period and Node Constraints, HENRY S. WEIGEL and JOHN E. CREMEANS.

The minimum-cost multi-commodity flow problem over capacitated networks subject to resource constraints has been treated in previous papers. Those treatments considered only capacitated arcs and a uniform unit of measure like short tons for all commodities. This paper treats the effect of constraints on the nodes of the network, measures commodities in their "natural" units and expresses the network capacities in vehicles per time period—in some cases giving a more accurate representation of the capacities of the network. The solution procedure using the column generation technique is described and computational experience is discussed.

WP8.10. On the Decomposition of the Out-of-Kilter Algorithm, HOANG HAI HOC.

By studying the application of the out-of-kilter algorithm, we realize that the underlying labeling process can be replaced by the search for a positive capacity chain in a modified network defined from the original one and the current flow. In a sparse network, in which subnetworks are linearly overlapped, such a search may be carried out by constructing a decomposition algorithm for finding all maximum capacity chains. Then one obtains a decomposable version of the out-of-kilter algorithm. To evaluate its merit some efforts have been devoted to study computational aspects of this decomposition.

WP8.11. On the Cones of Tangents with Application to Optimization Theory, M. S. BAZARAA and J.J. GOODE.

The cones of tangents have been introduced by Abadie and used by others to construct different constraint qualifications. We highlight the significance of the polars of these cones not only from the point of view of optimization theory (mathematical

programming) but also from the general theory of differentials. We show that elements of such polar cones represent a natural extension of one-sided directional derivatives. As an application we develop an extension of the Kuhn-Tucker necessary conditions for nondifferentiable functions under various constraint qualifications. Under some moderate convexity assumptions these criteria are also sufficient.

WP8.12. Cost Minimization of Refuse Collection Operations: Some Applications of a Basic Model, MICHAEL J. C. MARTIN and ALAN E. ROTHWELL.

In an earlier paper Coyle and Martin (O.R.Q. 1968 Conf. Ed. April, 1969) described models for minimizing refuse collection costs of a U. K. city. These models minimized costs of a household collection system using metal bins and a weekly collection frequency. The present paper describes some extensions of the earlier models and their use in examining minimum collection costs when:

(1) Collection frequency is varied.
(2) Householders pre-position bins on side-walk.
(3) Refuse is stored in paper sacks instead of metal bins.

WP8.13. Conversational Computerized Statistical Analysis in Business, JOE BULAT.

A significant application of the computer is in the area of statistical analysis of data for managerial decisions. The problems with existing computerized statistical systems will be evaluated within the framework of managements requirements with regards to data handling, capabilities, ease of use, and costs. BASIS, a conversational statistical system, has been developed to eliminate many of the time delays and costs usually associated with computerized processing of statistical data. It permits interaction with the computer through a remote terminal for a wide variety of applications; and requires no knowledge of computer programming. Examples of the use of the system to solve managerial problems are provided.

WP8.14. On Cycling in the Transportation Problem, WLODZIMIERZ SZWARC.

The paper presents a proof showing that the regular simplex method procedure for solving the transportation problem always produces the optimal solution in a finite number of steps.

The theorem stating that cycling is impossible in the transportation problem was proved for the case when the number of sources (or destinations) does not exceed five. The proof for the general case would be complete provided we prove this theorem for some special case of the assignment problem.

WP8.15. A Linear Programming Model for Gas Pipeline Distribution, KHOSROW ZAMANI.

At the North Thames Gas Board a linear programming system is being developed to 'optimally' select gas producing plants. 'Optimality' is defined as being able to meet the daily demand at the lowest cost.

The main objective of this paper is to formulate specific constraints which will prevent the linear programming from selecting plants that are infeasible, i.e., plants which may not be able to supply gas to some of the consumers. Following the theoretical work and using the actual data, 119 constraints were formulated. These contraints are used in addition to nine hundred constraints of the linear programming system to ensure feasibility of solution.

WP8.16. The Use of Multiple Routing Techniques for Capacity Restraint Assignments, BRUNO R. WILDERMUTH.

Among the various methods used to assign vehicle trips onto road networks, capacity restraint techniques consistently produce the most realistic results. However, because of inherent limitations of minimum path procedures traditionally used with traffic assignment techniques, many iterations are usually required to achieve stable flow conditions. The use of a multiple routing technique is described which greatly reduces the

need for iterative adjustments because of the ability of that technique to generate a multiple of directional best path between any pair of nodes. This technique helps to achieve stability of flows with operational efficiency not yet achieved by existing methods.

WP8.17. Large Scale Transportation Problem: Practical Solution for Real Life Problem, BENJAMIN LEV.

This paper is an application of the classical transportation problem, it deals with the distribution of beer of one of the major Beer companies in the Eastern United States.

There are over 20 different products to distribute, which yield to a transportation problem with 120 sources and 12,000 destination. By means of pooling together similar types of product and neighboring destinations, we end up with seven transportation problems of sixe 6X105. We decompose the capacity (sources) of the breweries into seven production groups and by comparing the dual variables of the sources we approach the optimal solution. Numerical results will be given in the paper.

WP8.18. A Family of Marginal Resource Allocation Techniques, BURTON S. LIEBESMAN.

Consider the resource allocation problem of minimizing a separable convex cost function, subject to an additive, integer-valued constraint. Generalized Lagrange multipliers are used to find a necessary and sufficient condition for optimality, subject to a total resource constraint which may differ from the desired value. Algorithms are developed which step from one optimal solution to another, until the optimum feasible solution is reached. These algorithms are faster than the corresponding dynamic programming algorithm. An example involving quadratic cost functions is solved. The techniques are extended to nonconvex cost functions, and to knapsack problems involving separable, convex cost functions.

WP8.19. Conceptual Data Processing—A New Idea, GLENN G. FOSTER.

The effectiveness of information retrieval systems is dependent upon the users ability to extract exactly that information required. A method for classifying information with respect to its conceptual content has been developed. Since people think in concepts, less problems are encountered in establishing dialogue with the information retrieval system. This system uses a binary decision process for classification, permitting the highest level of human objectivity and a data structure corresponding to a universal set which defines sub-sets in terms of relative concepts. Casyndekan's system allows extraction of information with a high level of both discrimination and recall.

WP8.20. Estimating Multidimensional Utility Functions on the Basis of Revealed Preferences: An Application to Clinical Decision Making, BRIAN E. FORST.

Nearly all attempts to estimate multidimensional utility functions have relied solely upon responses to hypothetical lotteries. This paper criticizes that approach on several grounds and proposes the alternative of combining these responses with observations of actual choice behavior under uncertainty. The estimation procedure is described, along with difficulties inherent in the approach. The medical diagnosis and treatment selection problem is carried throughout as the archetype situation to which the discussion applies. The paper presents results of an application of the technique to a specific clinical situation.

WP8.21 Why Not Use BASIC for Operations Research Programming Needs, C. JOSEPH SASS.

Operations research projects require computer capability to process time-consuming calculations necessary to model systems. BASIC programming language can provide the researcher with an additional tool for modeling. BASIC is easy to learn yet is technical enough for solving sophisticated applications. Why use BASIC? First, the researcher can eliminate errors that occur when another programmer writes the solution for a problem.

Second, the user need not be a technical programmer since English-like statements are used. Third, a complete set of matrix operations reduce significantly the number of instructions required for data manipulation. Finally, free format provides great flexibility.

TA1. Panel on. Tactical Air Power in the Eighties.

Between 1914 and 1971, fantastic changes in missile and aircraft technology and dollar cost took place. Yet *in actual combat* the employment of tactical air power and air defense has been essentially almost unchanged. Dogfighting remains the preferred mode of air combat, bombing in daylight predominates, the offense has the edge over the defense most of the time, and the effectiveness of tactical air power is largely a matter of debate, the true answer to which is disclosed only to the victim. Will this state of affairs continue? If not, how will it change and why? The discussion will focus on the implications of technology, the extent to which it has been delivered or failed to deliver in the past, the interplay between offense and defense and similar topics and will discuss questions such as the following:

How could/should/will our design, employment and force structure philosophies evolve over the next 20 years? What about those of other nations? Is anybody on the edge of a real technological revolution?

In what ways does new technology favor air defense? The offense? If air defense is favored on balance, is this good or bad for us in a major non-nuclear combat?

If we have a significant non-nuclear war twenty years from now (and none in the meantime) what will we conclude after it's over? Air Defense reigns supreme? Missiles and unmanned aircraft would have been better? We didn't design for *that,* but things worked pretty well anyway? We really fouled up?

*TA2.1. Evolving Techniques for Health Systems Analysis, CHARLES D. FLAGLE.

The operations analyst enters the health care system bearing a heritage of techniques and approaches with military and industrial origins. In the context of a new set of problems, with different objectives and decision-making structures, the nature of operations research and its relationship to the client may be expected to take on new forms. Experience to date reveals some directions and emphasis in health systems analysis. Problems of pattern recognition and classification, and problems of parameter estimation through consensus and accounting for population dynamics and technology in manpower planning, are forcing extensions of theories and structure.

*TA2.2. Progress in the Public Support of the Health System Concept, GILBERT D. BARNHART.

This paper will analyze the acceptance and utilization of systems concepts in the Congress, the Executive Office of the President, and in the Department of Health, Education and Welfare. Attention will be given to the historical growth of acceptance and to the application of systems analysis in staff work and in support of extramural research and development in health services.

*TA2.3. Community Health Care—Problems and Progress, WILLIAM J. HORVATH.

No single organization or system is responsible for providing the wide range of services encompassed by community health care. This condition has resulted to date in overlapping functions, poor communications among groups, and generally inefficient operations. Consequently, the quality and availability of medical care has been less than optimal. As yet none of the proposed solutions has received a thorough evaluation but operations research workers have achieved some results. Further suggestions for dealing with these community health problems will be discussed.

*TA2.4. Progress in the Application of OR/SA to Hospital Services, JOHN R. GRIFFITH.

Progress is being made in the implementation of operations research techniques in

hospitals. However, there is still a considerable gulf between the growing number of operations research studies in health eare and their practical permanent utilization in hospitals and other health care facilities. Lags in the implementation of computer technology and shortages of skilled manpower are factors in this. At the University of Michigan, experience with a hospital management monitoring system has revealed other significant factors, such as unrealistic model constraints and inadequate information systems. Such experience in a demonstration project at two Michigan hospitals will be used to illustrate and amplify the general application problem.

*TA3.1. A Survey of Large-Scale Mathematical Programming, LEON S. LASDON.

Recent developments in large scale linear, nonlinear, and integer programming are reviewed. Both theoretical and computational work will be included. An attempt will be made to predict useful future courses of investigation.

TA3.2 A Decompositon Algorithm for Finding Shortest Paths In a Special Type of Sparse Network, JIN Y. YEN.

This paper presents a decomposition algorithm for finding the lengths of shortest paths between all pairs of nodes in a sparse network than can be decomposed into m independent subnetworks and a "barrier" subnetwork that intersects the m subnetworks. The significance of this algorithm is that it requires approximately only one half of the computations required by Land and Stairs' algorithm (1967) which is the most efficient algorithm available for solving the problem in the above-mentioned type of sparse network.

*TA3.3. Progress in Large-Scale Optimization, ARTHUR M. GEOFFRION.

A discussion of several recent theoretical and computational developments in large-scale optimization, with particular emphasis on the emerging field of large-scale integer programming.

*TA3.4. A Primal Method for Linear Programs with Coupling Rows and Columns, JAMES K. HARTMAN.

Many large scale linear programs have constraint matrices consisting of a large number of blocks along the diagonal with an L-shaped border of coupling constraints and coupling columns. A primal algorithm has been developed for this class of problems. The algorithm is a compact inverse version of the revised simplex method which exploits the problem structure to achieve a compact representation of the basis inverse matrix. Updating the quantities required for this representation can be done in an efficient manner. Limited computational experience on a special class of production planning problems is available.

*TA3.5. Naive Linear Programming, JAMES E. KALAN.

Constraint matrices for large linear programs tend to be supersparse in the sense that the number of distinct non-zero elements is "small." Allowing for no other special structure, such matrices may be core resident.

The product form of inverse is not as efficient as an extended Gauss eliminat on scheme, with which a significant portion of the basis "inverse" exists within the constraint matrix.

Computational results are presented for an in-core code applied to a sample of large linear programs.

*TA3.6. Comments on Dynamic Optimization, GEORGE B. DANTZIG.

This paper will survey approaches to problems involving dynamic or staged systems.

*TA3.7. A Algorithm for Structured Quadratic Programs, MICHAEL GRIGORIADIS.

A partitioning method for large quadratic programs with linear inequality constraints exhibiting the usual block diagonal structure except for a few coupling columns

will be presented. The projective properties of the process of elimination of variable from an undetermined system of equations, representing the active constraint set at a feasible point, will be used to reduce the problem to a finite sequence of smaller quadratic programs. The computational aspects of the method will be discussed in detail.

*TA4.1. Simple Approximations for Some Constrained Continuous Review Inventory Systems, EVAN L. PORTEUS.

A multi-item, single echelon inventory system with backlogging, deterministic lead-times, and demands arising from a Poisson process with an unknown rate is considered. Only the class of stationary continuous review *(s, S)* policies is considered. We start with a short run "budget" constraint and end with the best long run *efficient* policy which satisfies that constraint. Obsolescence and an emergency supply procedure are dealt with directly. Approximations are made so that an analytic solution for the reorder quantity, *S*, is found as a function of the reorder level, *s*, and a Lagrange multiplier.

*TA4.2. Minimax Inventory Models, EDMUND M. NOTZON, III.

This paper treats a single commodity, periodic review inventory model. In each period nature selects the distribution function of demand from a class of distribution functions. Since we do not know which distribution function nature will select, we seek to minimize the maximum expected cost we could incur. Under this criterion, we establish analogs to Scarf's and Veinott's results on the optimality of *(s, S)* policies. Another analog to Scarf's result holds if the sequence of demands is chosen by nature from a compact set. This optimal policy depends on the history of demands, so we have a non-Bayesian learning procedure.

*TA4.3. A Multi-Facility, Single-Supplier Inventory Problem, FELIPE K. TAN.

A system wherein two facilities subject to stochastic demands are supplied by a central warehouse is considered. The warehouse orders from exogenous sources every T time periods and allocates to the facilities in every period. The optimal ordering and allocation policies are characterized for convex cost functions with backlogging of demand and no transhipment between facilities. The characterization is further sharpened for the case where the cost functions are separable in their variables.

TA4.4. Comparison of Alternative Inventory Supply Policies: Multipurpose vs. Special Purpose Equipment, GARY J. HANDLER.

Two modes of supplying demands for n different product types are considered. One method is to produce a different type of equipment for each demand type. The alternative is to produce a more complex model which can be converted to satisfy the different demands. General conditions for optimality are derived. Using a new approximation formula, a functional comparison of the supply systems is given for independent Poisson demands.

TA4.5. Inventory Allocation Among an Assembly and Its Repairable Subassemblies, EDWARD A. SILVER.

In this paper we consider a major assembly composed of two or more subassemblies. The failure of any subassembly causes the major assembly to not function. Failed subassemblies can be repaired. A total investment in stocks of spare components is to be distributed among the various subassemblies and the major assembly in some best fashion (e.g. to minimize backorders for the major assembly). This is a complicated problem. relevant factors are the failure rates, unit costs and repair times of the various components. For the case of Poisson failures, the author develops a solution which is a compromise between theoretical optimality and practical usefulness.

TA4.6. Optimal Positioning of Inventory Stock in a Multi-Echelon System, GEORGE F BROWN, JR., LESTER P. SILVERMAN, and RALPH J. VANNI.

This paper considers optimal stockage and resupply policies for an inventory system

in which the cost and time for resupply can be altered by various logistical expenditures, including the pre-positioning of parts at intermediate echelons of the system. At stations on the lowest echelon, demands arise due to part failure. With some probability, the part can be repaired at this echelon. Spare parts may be obtained from inventory, through repair, or by ordering. Minimum cost stockage and re-ordering rules are derived for each echelon. An application of the procedure to the Naval aviation support system is described.

TA4.7. Inventory Systems With Imperfect Asset Information, DONALD L. IGLEHART and RICHARD C. MOREY.

This paper deals with inventory systems in which the stock record may not be in agreement with the physical stock due to errors introduced through imperfect inventory counts and normal operating inaccuracies. The approach taken is to consider for an individual item the necessary modifications to a predetermined stocking policy in order to insure, at minimum total cost per unit time, that the likelihood of a "warehouse refusal" is held below some prescribed level. The proper depth and frequency of the inventory count procedure is also described for a "trigger" based either on the time or cumulative number of demands since the last count.

TA4.8. Optimization of Batch Ordering Under Deterministic Variable Demand, SALAH E. ELMAGHRABY and VISHWAS Y. BAWLE.

We consider the problem of the optimal ordering schedule to satisfy a given demand pattern over a finite planning horizon when ordering must be in batches of size $Q > 1$, with and without 'setup' cost. A dynamic programming model is constructed. The number of stages are minimized through the characterization of a "complete" set of periods in which ordering must take place, and through consideration of the role of initial inventory. The state space and the decision space at each stage are also minimized through considerations of dominance, bounding and feasibility relative to established properties of the optimal schedule. All this results in a most computationally efficient algorithm. The procedures are illustrated by numerical examples.

TA4.9. Continuous-Review *(s, S)* Inventory Models with State-Dependent Leadtime, DONALD GROSS and CARL M. HARRIS.

This paper describes the development of a continuous-review *(s, S)* inventory model with state-dependent stochastic leadtimes. The demand on the inventory system is assumed to be a Poisson random variable, and the order-filling portion of the replenishment leadtime is allowed to depend on the number of outstanding orders (i.e., to be state dependent). The inventory state probabilities which are required in order to optimize the cost function with respect to s and S can be obtained via a queuing analysis on the order-filling process. The theoretical development and computational aspects are discussed.

*TA5.1. Modelling for Air Traffic Control Systems, AMEDEO R. ODONI.

In this paper we review several classes of models of ATC-related systems that have been presented over the years. These models cover the complete spectrum of ATC activities: surface traffic movement, runway utilization, terminal areas, and enroute traffic. Outstanding work in each area is summarized and criticized. The employed techniques range from the purely analytical to real and fast time simulations. Topics for possible future work are also identified based on the present review. Finally, an extensive annotated bibliography is included.

*TA5.2 Air Terminal Queues under Time-Dependent Conditions, B. O. KOOPMAN.

The queues formed by aircraft awaiting landing clearance have usually been treated either by machine simulation, or analytically as stochastic processes with time-independent transition probabilites (possessing stationary solutions). In contrast to this, the present analytic paper regards the queue-developing process in question as strongly

time-dependent, with a diurnal periodicity. The case treated is that of Poisson arrivals at time-varying rates, and Poisson landing clearances, either constant or time-dependent. Application of classical theory determine the properties of their solution, showing in particular that when the coefficients are periodic, a unique solution is periodic with the same period, all other approaching it geometrically with increase of time.

*TA5.3. Analysis of Pilot Warning Indicator Performance Using Digital Computer Fast-Time Simulation, J. RAY RUETENIK, WILLIAM R. LANGE, and JOHN H. THOMPSON.

Three pilot warning indicator systems (PWI) for collision hazard avoidance in terminal-area traffic are analyzed using digital computer fast-time simulation. For the traffic model, flight tracks recorded in the Atlanta terminal area over an 11-hour period during August 1967 are used. The basic PWI system alarms when flashing xenon beacons on intruder aircraft come within a preselected range. To maintain the missed alarm rate under 10 percent of the hazard epochs, the ratio of alarm to hazard epochs is about 17/1. Two modifications to the basic system, beacon vignetting and range-rate discrimination, are shown to reduce the false-alarm rate by about 75 percent.

TA5.4. Optimal Self-Perpetuating Flow in a Closed-Loop Air Traffic Control Network, JAMES W. EYSTER.

FAA Advanced Flow Control Procedures are analyzed from a systems concept to determine the magnitude of air terminal interactions in a closed-loop network. Based on a system weighted-delay objective function, aircraft flow is metered from one terminal to the next. Terminals are assumed to have one facility with a fixed capacity for servicing both arrivals and departures. A prescriptive model is developed for deterministic flow in a given terminal network configuration and is extended to incorporate stochastic flows. A sensitivity analysis is performed to determine the effect of non-optimal flow on system delay.

*TA6.1. Recent Research and New Developments in Budgeting Theory and Practice—A Survey and Evaluation, ROBERT F. BYRNE.

This paper reviews and summarizes recent research on budgeting processes. Particular attention is focused on (a) capital budgeting under conditions of risk and/or uncertainty and (b) governmental budgetary practices. In the first of these areas, research is categorized under three broad areas: (1) development of normative models for capital investment under risk, using "traditional" market equilibrium analysis as in the Miller-Modigliani approach, (2) development of portfolio models which attempt to give explicit representation to the multi-dimensional character of the objectives of a firm, and (3) attempts to provide insight and improvement for commonly employed practices (e.g. payback period usages) of business decision-makers in dealing with their problems. Recent contributions in each area are examined, and some tentative conclusions suggested for possible future advances. Thus, the place of capital budgeting in the business budgetary process is re-examined and evaluated in a variety of forms. In governmental budgeting various areas of interest are examined, including model of PPBS (=Program Planning Budgeting Systems) along with simulations and econometric projections of other types of budgetary mechanisms such as appropriation-type budgets.

*TA6.2. A Basic Approach to the Evaluation of Risky Interrelated Investments, FREDERICK S. HILLIER.

When evaluating proposals for capital investment, two important factors are risk and the effect of interrelationships of various kinds. This paper studies how to simultaneously take both considerations into account in order to determine the best overall combination of projects to approve. Adopting present value (treated as a random variable) and expected utility of present value as criteria, it focuses on a basic approach of this kind developed in the author's monograph, *The Evaluation of Risky Interrelated*

Investments, and extends it further in terms of formulation and interpretation needed for implementation. Computational experience also is reported and analyzed.

*TA6.3. CC and LPUU Combinations for Treating Different Risks and Uncertainties in Capital Budgets, R. F. BYRNE, A. CHARNES, W. W. COOPER, and K. O. KORTANEK.

Chance Constrained Programming and Linear Programming under Uncertainty are joined to deal with different risks and uncertainties encountered in capital budgeting. This includes payback period protection via chance constraints formulated to cover (or bound) a possible loss of future opportunities. It also includes liquidity requirements to provide protection against possible cash (or liquidity) shortages at specified times. The case of arbitrary discrete distributions is examined and formulations developed to model economic, statistical, and technological decision interdependencies. Relations to geometric programming are indicated prior to reducing these formulations to zero-one integer programming (deterministic) equivalents. Duality relations obtained from these formulations provide separate evaluators for yield, risk, portfolio and liquidity effects of cash investment. Finally, relations to "Balas-type" subsidy and penalty adjustments are noted.

*TA6.4. A Model of Capital Budgeting Under Risk, BERTIL NÄSLUND.

The problem of allocating limited funds between several investment alternatives is discussed using chance-constrained programming. The probabilistic constraints state that the cash flows associated with the projects must exceed a certain amount at least with a specific probability set by the decision-maker.

It is shown how these constraints can be transformed to determine the financial reserves needed to give the desired protection against low cash flows.

Acceptance criteria for investments projects under risk are determined using the Kuhn-Tucker conditions both with perfect and imperfect capital markets and computational possibilities are discussed.

Some effects on investment behavior of alterations in the interest rate and the variance are shown.

*TA6.5. Some New Views on the Payback Period and Capital Budgeting Decisions, H. MARTIN WEINGARTNER.

The Payback Period has been dismissed as misleading and worthless by most writers on capital budgeting at the same time that businessmen continue to utilize this concept. This paper seeks to identify the problems which businessmen try to solve by use of the payback period, so that better tools can be provided for solving these, since neither the present value nor the internal rate of return does so.

In the course of the analysis the payback concept is considered in its role as a criterion versus a payback constraint, payback and liquidity of capital assets and the liquidity requirements of the firm, payback as a break-even concept, and payback as a crude measure of the rate of resolution of uncertainty. While payback is not advocated for capital investment decisions, the reasons for its popularity need to be understood before it is possible to develop superior alternatives.

*TA6.6. PPBS—An Analytic Approach, TIMOTHY W. RUEFLI.

Although PPBS encourages the use of analytic techniques in decision-making, little use has been made of analytic techniques to evaluate the implications of PPBS itself. This chapter will present an overview of PPBS and then will outline the development of a model of decision-making in a decentralized organization. This model will be related to the structure and process of PPBS and will be used as a vehicle for analyzing some of the implications of PPBS for organization structure and the decision process.

*TA6.7. Defense Budgeting: Organizational Adaptation to Environmental Constraints, JOHN P. CRECINE.

This article describes the annual budgetary process found in the U. S. Department of Defense until the Spring of 1969. The process is largely organizational and annually generates the annual appropriations bill or budget consistent with external constraints on the total for defense. These external constraints are almost always fiscal and evolve from the interdependent nature of national policymaking with regard to tax burdens, deficit spending, and resource needs for non-defense activities of the Federal Government. In the budgetary process described here, the military services requested resources that greatly exceeded the limitation on the defense total, leading the Office of the Secretary of Defense to cut these requests back until they fell within the limitation. The structure and dynamics of this process are examined in detail. Also discussed is the relationship of the Planning, Programming, Budgeting System (PPBS), introduced in DoD in 1961, to the annual appropriations process.

*TA6.8. Towards a Theory of Public Budgetary Decision Making, DONALD GERWIN.

In a previous paper the author developed a computer simulation model of the process by which the operating budget is allocated in a large urban school district. In this paper a set of interrelated propositions about the budgetary process, which are meant to apply to a wide class of public organizations, are developed from the school district study and other pertinent research. The overall decision process is hypothesized to involve first a set of preliminary expenditure decisions, then a comparison of forecasted revenues to total spending, and finally the revision of decisions to balance the budget. Within this framework propositions are developed concerning revenue forecasts, subunit allocations, compensation decisions, and debt service. In general they illustrate the importance of the administrator's desire to mitigate conflict over the contents of the budget By contributing to our understanding of the way in which such organizational factors influence allocations this research should aid in making budgetary reforms such as PBBS more effective.

*TA6.9. The Process of Budgeting II: An Empirical Study of Congressional Appropriations, O. A. DAVIS, M.A.H. DEMPSTER, and A. WILDAVSKY.

This paper is a study of the process by which funds are appropriated in the United States Government. It reviews certain systems of stochastic difference equations, which are taken to represent behavioral rules, and on the basis of estimates from all agencies in the non-defense sector of the Government the authors argue that these linear systems do summarize accurately certain outcomes of the budgetary process. In addition to the extensive estimation, the basic methodology of the study is carefully discussed, certain statistical summaries of the results are presented, and a summary report is made of intensive studies of a select number of agencies whose budgetary behavior appeared to have changed during the period under consideration. The authors present evidence which suggests that there are reasonable explanations for these changes.

TA7.1. Some Discrete-time Models with Linear Transition Rate, HERMAN STEIN.

New finite-state, discrete-time models are developed under the condition that the probability of going from state (i) to state (i + 1) is a linear function. These models may be motivated by an urn scheme which has the Markov property. This finite Markov chain may be solved algebraically to yield the probability function. The method of generating functions is then employed to obtain the moments and limiting functions. Finally, the models are used to describe some aspects of a hospital blood bank inventory system.

TA7.2 The Effect that the Probability of a Successful Approach Has on the Sequential Landing Rate of Like Aircraft, EDWIN M. GOLDBERG.

The sequential landing of like aircraft is identified as a Markov Process and the effect of a probability of successful approach less than one on the landing rate of six like aircraft is investigated. The essential results of this investigation are shown as graphs of

the probability of finding all aircraft landed as a function of the number of attempted approaches with the probability of a successful approach as a parameter.

TA7.3. Location of Inspection Stations in an Assembly Line by Integer Programming, LLOYD A. SWANSON and DONALD J. AGOSTINO.

The allocation of inspection effort in an assembly or production line is determined by a mixed integer linear programming algorithm. Items of product enter the assembly line in batches or continuously, and a certain percentage incur defects at various stages. At the end of every stage there is the opportunity for locating an inspector, who examines all the units which pass through that stage. Initially, all defective units are rejected. Subsequent models allow for replacement of defective items, inspection errors, and constraints on the number of inspectors. Examples are given and solved by a Branch and Bound Mixed Integer algorithm.

TA7.4 Funds Allocation Model, WALTER L. DE VRIES.

This model selects an investment portfolio from a given population of possible investments (bonds, stocks and mortgages) that has the maximum effective yield over a given period of years. Investment policy constraints, risk evaluations, expense rates, future interest assumptions as well as data describing the investments are inputs to the model. Also, the model can be used retrospectively to evaluate the actual performance of a portfolio.

TA7.5. Cobra Tank Assessment Model, C. E. MANLEY and W. F. FULKERSON.

The COBRA/TANK ASSESSMENT MODEL (C/TAM) depicts combat between helicopters mounting missiles and tanks defended by air defense weapons. A Markovian view of combat is incorporated to reflect the status (states) of the combatants. The method of finite differences is used to solve a system of coupled first order differential equations which describes transfers among the various states. Model parameters are directly related to environmental and equipment performance characteristics. C/TAM was developed to study the effect of air-to-ground and ground-to-air detections upon helicopter performance against tanks. Model results include expected equipment losses, ammunition expenditures, and engagement times.

TA7.6. Optimal Strategy for the Expansion of Airport Terminals: A Cost-Effectiveness Analysis, RICHARD DE NEUFVILLE.

A cost-effectiveness analysis of airport terminal design is presented which focuses on the major alternative at issue today: the degree to which vehicular systems should substitute for constructed facilities like finger piers. The basic capacity expansion problem involving the tradeoff between economies of scale and the cost of committing capital prematurely, discussed by Manne, is broadened to include consideration of the possible advantages of labor-intensive systems over capital-intensive construction. A solution to this general problem is obtained. Using capacity, travel time, reliability and design flexibility as measures of effectiveness, specific recommendations for optimal terminal designs are developed.

TA7.7. Selection of Experts, HARRY E. EMLET, JR., JOHN L. DAVIS, and IRVING J. CASEY.

Estimation by experts of data otherwise not readily available is increasing as an adjunct to quantitative analysis. Such estimation first requires selection of the experts on the given subject. The literature reveals essentially no research on selection methods despite their importance. This study considers selection of medical professionals judged expert by the medically informed community. Alternative methods are identified and preferred option is selected on the basis of logical, analytical, statistical, and practical considerations. Preliminary quantitative results of testing and applying the preferred option are presented. The methods are applicable to selection of experts in other areas.

TA7.8. A Validated Model for the Allocation of Nursing Personnel in an Extended Care Facility, JUDITH S. LIEBMAN, JOHN P. YOUNG, and MANDELL BELLMORE.

A mathematical programming model has been developed which uses current nursing attitudes about the effective utilization of personnel to predict the assignment of nursing procedures within an extended care nursing unit. This model provides a method whereby hospital administrators can efficiently and economically investigate the effect of alternative nursing staff configuration on the direct care of patients. A variety of psychometric and operations research techniques were used, including a Q-sort experiment to measure attitudes, branch-and-bound, and the out-of-kilter algorithm. The validity of both the model and the objective function coefficients was demonstrated by successfully simulating an on-going process.

TA7.9. Modeling of a Class of Finite Queuing or Repairman Problems with GERT, MICHAEL H. BRANSON and BHARAT SHAH.

In this paper, certain conditional distributions needed for GERT network modeling of queueing (repairman) problems are expressed as functions of the moment generating function of one random variable and with the parameter of an exponential random variable. With these results, a wide class of single server repairman problems with exponential failure and general repair times can be modeled. Several examples illustrating the applications of the results are presented. Output of the analysis includes the steady state distribution, meantime to system failure and other parameters. Transient analysis may also be performed.

TA7.10. Nonserial Dynamic Programming: Multilevel Procedures, UMBERTO BERTELÉ and FRANCESCO BRIOSCHI.

Nonserial Dynamic Programming is an optimization technique which applies decomposition for the solution of discrete unconstrained problems in which the objective function is the sum of components each depending, in general, only upon a subset of the variables of the problem. Different procedures for its efficient solution have already been discussed in the literature. This paper presents a new optimization procedure which is more general and powerful of the preceding ones.

TA7.11. Operational Inventory Control with Seasonal Demand, REIN PETERSON and JOSEPH THOMAS.

Most theoretical formulations of inventory problems (for example some simple (q,r) policies or Wilson E.O.Q. formulations) do not explicitly include seasonality of demand. In this paper we study some operational decision rules that account for a known seasonal pattern Two seasonal demand patterns are studied using an optimal stochastic dynamic program. The heuristics we recommend achieve 90 per cent or better (on a total cost basis) of the benefits of the stochastic dynamic program but are operationally easier to implement. Furthermore, our heuristics behave better by 25 per cent than the Wilson E.O.Q. model.

TA7.12. A Convex Programming Algorithm, R. JAGANNATHAN.

In this paper we furnish a computational procedure for solving a Convex programming problem whose constraint set is a Compact Convex Polyhedron. The algorithm is sequential in nature, producing a sequence of feasible solutions whose convergence to an optimal solution is also proved. A special case of the algorithm involves solving sequence of parametric LP problems.

TA7.13. On Multicommodity Maximal Dynamic Flows, MANDELL BELLMORE and RAMAKRISHNA R. VEMUGANTI.

Ford and Fulkerson have shown that a single commodity maximal dynamic flow can be obtained by solving a transhipment problem associated with the static network. However, this result cannot be extended to the multicommodity maximal dynamic flow problem. It is shown that the multi-commodity static flow produces feasible solutions to

the multi-commodity dynamic flow and also provides useful bounds on the value of a multi-commodity maximal dynamic flow.

TA7.14. Computational Experience with Applications of State Increment Dynamic Programming to Industrial Management Problems, R. N. KAPUR.

In 1965 Robert Larson developed a new approach called state increment dynamic programming to reduce the excessive fast-access computer storage required by conventional dynamic programming. In theory, Larson's approach considerably reduces storage needs but retains the general applicability and other desirable features of dynamic programming. This paper reports on the computational experience gained applying this new method using both small and large computers (IBM 1130 and IBM 360). The dynamic programming models used are drawn from real situations in industry as well as from texts. The results obtained pinpoint those cases where the method can be successfully applied and also where it fails.

TA7.15. Optimal Control of Research and Development Expenditures, CARL W. HAMILTON.

A mathematical model is developed to assist the selection and funding of research and development projects. The main innovation is the use of discrete optimal control theory to find the optimal expenditure rate for each project during each period of the planning horizon. (An expenditure stream of zeros indicates non-selection). Uncertainty of total project cost is explicitly recognized, together with the functional interdependencies among projects and the multiperiod staging requirements on the final results. Economic interpretations of the discrete maximum principle are provided together with numerical results for certain test cases.

TA7.16. A Mathematical Programming Approach to the Cost Effectiveness Analysis of a Family of Military Engineering Construction Equipment (FAMECE), WILLIAM G. SCOTT.

An integer programming approach to selection of the most cost effective mix of alternate types of engineering earth-moving equipment is formulated. The analysis is a fixed effectiveness type. An objective function which describes both the fixed and variable elements of life-cycle cost is minimized. A complex mission is reduced to a constraint set which insures that the solution satisfies a minimum level of effectiveness. The method described has broad applications to those problems in which system effectiveness can be described by a set of quantitative requirements.

TA7.17. A Schematic Schedule of Program Plan, YING C. CHUANG.

A comprehensive plan of the program would not be complete without a system of handling scheduling. Essentially, such a system integrates all given information by analyzing the personnel flow, funds, and facility availability into a workable plan. As an instrument for analysis, an algorithm can provide information on what and when happens if any of the parameters within the system are altered. In this paper, a scheme of program scheduling for the Center for Urban Education five year plan is presented and illustrated with some implication.

TA7.18. The Economics of Group Practice in Medicine, WILLIAM LAWRENCE.

This paper examines the group practice of medicine. The formation and workings of these groups are put into an analytical framework in order to look at costs and productivity. Furthermore, the economies of scale which result from group practice are described. Policy conclusions and planning implications are also discussed.

TA7.19. Public Sector Routing Models, ROBERT STRICKER and DAVID H. MARKS.

The problem of routing public sector vehicles such as refuse collection and snow removal where demand is characterized as fairly continuous along a street network is important due to the inherent costs of such procedures. Analysis of such routing

problems is seen as a form of chinese postman (minimum edge covering tour) problem with important changes due to the fact that time and capacity constraints force the generation of multiple routes. A heuristic for decomposition in large scale networks is presented along with computational experience on a Cambridge, Massachusetts example

TA7.20. A Square Root Law for Fire Engine Effectiveness, PETER J. KOLESAR.

Basic dimensional analysis and some specific abstract mathematical models lead to the hypothesis of an inverse square root relationship between response time to incidents and the number of fire companies stationed in a region. Semi emperical confirmation has been obtained using simulations of dynamic systems. The usefulness of which a relationship for strategic and tactical decision making is discussed.

TA7.21. Controllability and Observability in Dynamic Operations Research Models, B. L. CAPEHART and R. B. WADSWORTH.

The concepts of controllability and observability introduced by Kalman play an important role in both theoretical and practical aspects of modern system theory. The conditions of controllability and observability are of well known importance in determination of existence of solutions to dynamic optimization problems. Many operations research studies result in the creation of dynamic models in which the operating behavior is described using differential equations. The importance of controllability and observability considerations to some of these operations research models (such as inventory systems, economic systems, and production control systems) is illustrated in this paper.

TA8.1. A Markovian Analysis of Performer-Oriented Systems, RONALD LESSING and WILLIAM B. WIDHELM.

This paper contains a unified Markovian analysis of performer-oriented probabilistic sequencing systems. The systems are expressed in terms of a linear model with three stages. The first, an operational stage, is one in which the error-level distribution (state-vector) is altered due to any operation on the products. The second, a branching stage, is one in which the products are inspected and dispersed. Finally, during the third stage, corrected items are merged with the acceptable products. By introducing two special matrices, the "filter" and "profile" matrices, the resulting Markovian analysis easily handles both the transient and sensitivity responses.

TA8.2. Grade Acceptance Simulation Model, E. B. COHEN, S. L. KOHR, and D. J. LOUICK.

A computer simulation was used to study the public acceptance of a new grade of a product. A Markov model was constructed for grade purchases. The probability for individual users to change grades was based upon market share and subjective value to users. From this theory, a set of differential equations was derived for the expected market shares of each grade by population sub-groups. Market shares over time for each grade were computed as functions of quality and price. Most of the coefficients in this computer model could be determined by solving for the conditions necessary for market stability.

TA8.3. A Determination of Resource Requirements for an ASW Mission, J. A. WHITE and K. E. CASE.

The sequence of activities performed by an anti-submarine warfare (ASW) vehicle between submarine detection and eventual escape or destruction of the submarine is modeled as an absorbing Markov chain. The resource required in making a transition from state i to state j is treated as a random variable X_{ij}. Network analysis techniques are employed to determine conditional moment generating functions for resource requirements for the ASW mission. Conditional and unconditional means and variances are obtained for the resources required. Additionally, an alternate method is presented for

obtaining values for the means and variances for resource requirementss when X_{ij} is a constant.

TA8.4. A Study of Patient Load Patterns in a Community Hospital, GERALD R. ADLER and AMRIT L. GOEL.

The results of a two-year (1968-69) study to investigate the patient load in a medium size community hospital are detailed in this paper. Data for the study was collected manually by patient type (infant, pediatric, female etc.), sex, and reason for hospitalization (medical, surgical, maternity) for each of the ten hospital areas. Frequency histograms, time series plots etc. are analyzed for observing significant patterns. Hypotheses are postulated to explain any major trends and comparisons are made between various patient types and within the same type over time. The Intensive Care Unit patient load is analyzed in a similar fashion.

TA8.5. A Bayesian Approach to Determining the Sample Size for Testing of AF Weapons Systems, KENNETH E. BRANT and PAUL BRITT.

Demonstration plans for meeting maintainability criteria must be specified in contracts for Air Force weapons systems. A model is developed that incorporates subjective experience and approximate cost functions in a Bayesian approach to use the expected value of sample information to determine an optimal number of tasks to be demonstrated to meet the requirements. A comparison to both the conventional and to a decision theoretic approach gives the conditions under which each of the three techniques is preferred. For a real world example given the Bayesian model requires a considerably smaller sample size.

TA8.6. Systems Requirements for Operational Gaming, S. M. LINDSAY, J. C. ROBINSON, and J. A. BATTILEGA.

Experience in the use of large computerized war gaming models in an operational environment indicates that knowledge of model output controllability is required if a model is to be used for time constrained decision making. This paper defines a procedure called metamodeling which attempts to replace the large simulation with a smaller model, derived from the original, with known output controllability with respect to selected input parameters. The metamodel is exercised prior to the large model to define feasible combinations of input parameters, thus significantly reducing the turnaround time for a decision problem. Examples are given.

TA8.7. A Program for the Allocation of Government Expenditures to Stabilize National Income, SEDAT SAMI ERCAN.

This paper investigates and restricts itself to the question of "How should government expenditure be chosen to control the fluctuations of the economy in a potentially unstable situation?" An objective function is developed in order to maximize the minimum national income that occurs for a given period of time, assuming a fixed amount of government expenditure over the same period of time.

A dynamic programming technique, analytical in nature, is utilized; and a numerical example is given to show that the national income could be maintained at the same level by correct allocation of government spending.

TA8.8 Predicting Information Costs in a Management Information System, ROBERT T. RILEY and THOMAS A. WILLIAMS.

A significant shortcoming of current management information systems (MIS) is the user's inability to obtain any predictions as to the cost of specific requests for information. This paper defines the elements of information cost and demonstrates why a cost predictor is a vital part of the conceptualization of a MIS. Specific conditions under which cost predictors are especially significant are discussed, along with a brief look at some alternative methods of implementing these predictors. Finally, the costs and benefits of including a cost predictor in a MIS are discussed.

TA8.9. Casino Solo: Dynamic Extraction of a Monotonic Sequence from a Random Process, DAVID W. MATULA.

For Casino Solo a deck of cards numbered 1,2,---n is shuffled and dealt out one card at a time. As each card is observed the player can either accept the card if it is larger than the last card accepted or he can reject it. Thus the player extracts an ascending sequence as the deck is dealt. The problem of maximizing the expected length of the extracted sequence is solved as a one-dimensional dynamic program, and the problem of maximizing the probability of extracting a sequence of length k is solved as a two-dimensional dynamic program.

TA8.10. Stochastic Design Models for Location and Allocation of Service Facilities on a Network, SHALER STIDHAM, JR.

We consider several design models for the location and allocation of stochastic service facilities on a network of stochastic demands. The decision variables are the service rates at each node and/or the allocations of customers to service facilities. An algorithm based on generalized Lagrange multipliers is proposed. A comparison is made between the system-optimal solution and the competitive equilibrium in the case where customers are free to select their own allocations. The problem when both service rates and allocations are decision variables is shown in some cases to be equivalent to certain deterministic location problems already considered in the literature.

TA8.11. Modeling of a Satellite Airport System for Large Metropolitan Areas, INDER K. SUD and PAUL GRAY.

A systems approach is proposed for analyzing the satellite airport concept for large metropolitan areas. Various socio-economic factors that influence the airport location are considered. A mathematical model selects the number of satellite airports needed and computes desirable locations for them in the megalopolis. A trade-off analysis addresses such questions as the "value" attached to the travel-time and the noise exposure from an airport. Using San Francisco metropolitan area data, a cost/benefit analysis compares the satellite airport system with the conventional large centralized airport system.

TA8.12. Duality in the Transportation Model–II, V. SRINIVASAN and G. L. THOMPSON.

This paper utilizes duality in the transportation model for solving problems of post-optimization and parametric programming. Global operators are set up which transform a problem into another with different warehouse capacities and market supplies. The global operator is shown to be useful in determining 'real' shadow prices (changes in the optimum cost caused by a non-zero change in the rim conditions). The results for elementary global operators are then extended to represent global parametric operators needed in parametric programming. An algorithm is given for post-optimization and then extended to become yet another method for solving the transportation problem.

TA8.13. Kalman Filtering Applications in Economic and Inventory Systems, B. L. CAPEHART and C. S. BAUER.

Kalman Filtering is an optimal estimation technique for obtaining linear, least squares, estimates of states or parameters of linear dynamical systems. The technique is directly applicable to dynamic operations research models such as occur in economic and inventory systems, after these systems have been described in state variable notation. This paper presents an introduction to Kalman Filtering, and discusses the use of the Kalman Filter in estimating the internal states of dynamic operations research models and identifying unknown parameters in these systems. Several models are taken from the areas of economic, inventory, and production systems, in order to show the versatility of the Kalman Filter technique.

TA8.14. Simultaneous Decision Making Among Functional Areas of the Firm, WILLIAM W. DAMON.

The Holt, Modigliani, Muth, and Simon production scheduling model is extended to incorporate variables reflecting marketing and working capital management in a cash flow formulation. A constrained non-linear program is derived which is optimized by employing the SUMT program. Reasonable values were assigned to the parameters and the relative profitability of such a simultaneous formulation for a sequential model was tested. Initial results demonstrated an improvement of 25% by solving for the optimal values of the functional decision variables simultaneously.

TA8.15. An Evaluation of the Effectiveness of Mathematical Programming Models for R&D Project Selection, WILLIAM E. SOUDER.

Four representative mathematical programming models for R&D project selection and funding are developed, based on models in the literature. Project selection and funding decision data from several actual R&D projects are inputted into each of the models to ascertain which of the available projects to select and how much to spend on them. The portfolios prescribed by the models are compared with a low risk-low return portfolio and with the ex post optimum portfolio based on the actual success and failure outcomes of the projects. These comparisons indicate that although present day mathematical programming models for R&D project selection may not generally achieve optimum results, some types of models may be useful for improving the financial return from R&D investment decisions. Guidelines for developing improved models are outlined.

TA8.16. Optimization of In-Process Test Limits, HARLEY L. LYONS.

A method for optimizing in-process test limits on the basis of minimum total cost is described for a multistage manufacturing process, consisting of more than 400 discrete operations. An economic model is developed to display interrelationships of relevant manufacturing costs to process tests limits. Cost accounting, statistics, and regression analysis is then applied to define the required cost curves for completion of the model, and determination of optimum test limits.

TA8.17. Stochastic Multicommodity Network Flow, M. BELLMORE and J. W. CRAWFORD.

Ford and Fulkerson's deterministic (static) multicommodity network flow problem is extended by considering stochastic unit flow occurrences and stochastic flow durations. The network flow payoff is structured so that a variety of objective functions can be considered ranging from the expected value of the flow or the number of flow occurrences to payoff functions, such as revenue, defined on each or a combination of both. Two optimal solution methods are discussed.

TA8.18. Models for the Allocation of Vehicles to Parking Lots at an Urban Campus, R. GRAHAM J. MILLS.

An urban campus with a large number of spearate parking lots is considered. The allocation of vehicles to each parking lot causes conflicts which can be resolved by evaluating an allocation against various criteria. Linear programming can be used to minimize the total distance from parking lots to an individual's office while quadratic programming can be used to minimize the distance times the square of the number assigned from parking lots to office building. Another objective function considered is to minimuze the maximum distance each individual walks. Existing computer programs are used to evaluate the models and the results discussed.

TA8.19. Robustness of Tandem Queuing Models, HENRY D. FRIEDMAN and GENO TOLARI.

A tandem system has n stages in series, each stage containing one or more identical parallel channels. Service rates are generally different between stages. Poisson customers arrive at stage one and proceed through one channel of each stage on a first-come

first-served, unlimited queuing basis. Steady-state mean waiting time in the system is easily obtained analytically for exponential service times and also for constant service times. Intermediate cases using both Erlang and uniform service distributions were simulated. Results show that the constant service time model is robust.

TA8.20. Operations Research and the Administration of Justice, THOMAS L. MORIN.

The need for improvements in the effectiveness, efficiency, and fairness of the criminal justice system has been widely recognized. However, applications and implementations of operations research methodology in this area are still embryonic. Recognizing this, the purposes of this paper are twofold. First, we present a critical analysis of the applications which have been reported in the literature. Second, we develop relevant models which can aid in the administration of justice, especially in the area of court delay.

***TP2.1.** Operational Research in English Urban Problems, PETER THURSFIELD.

This paper surveys work by the Local Government Operational Research Unit of England in housing, transportation, education, land use planning, solid waste disposal, and land reclamation.

***TP2.2.** Urban Fire Protection: Analyses of Operations in the New York City Fire Department, EDWARD H. BLUM.

This paper describes analyses of urban fire protection being conducted jointly by the Fire Department of the City of New York (FDNY) and the New York City-Rand Institute. Underway roughly three years, these studies have a) created the perspectives, methods, approaches, and results of a new analytical field; b) transformed these research products into policies, helped put the policies into practice, and evaluated results; c) helped alter the FDNY's firefighting technology, the operation of its dispatching system, and the ways it manages and deploys its men and equipment; d) yielded (and continue to yield) gains in operational effectiveness valued at several million dollars per year; and e) helped the FDNY develop new problem-solving traditions and capabilities and improve its bases for future decisions and policies.

***TP2.3.** Planning the Criminal Detection Activities of the Police, VINCENT C. WATTS.

The studies described in this paper are concerned with two questions which confront a police force, what proportion of its manpower should be devoted to the detection of criminals and where these detectives should be located.

A model of criminal behavior is described which allows estimates to be made of the extent to which the detection of current criminals contributes to the reduction in the likely incidence of future crime in an area. These estimates, together with the results of other studies on the marginal productivity of detectives, will help police management to answer these questions.

***TP2.4.** A Case Study in Manpower Scheduling, LAWRENCE D BODIN, ALLAN TUCKER, EDWARD J. BELTRAMI and STANLEY M. ALTMAN.

This paper is based in part on a study that is being considered for adoption by one of the public service unions in New York City. The present manpower schedule allocates one day of the week as recreation to one sixth of the crews regardless of the demands for service. This gives a three-day weekend (Saturday, Sunday, Monday) to each crew every six weeks. Our proposed manpower schedule allocates recreation according to demands for service, allows each crew a better recreation schedule than he presently receives and insures that each crew receives about the same "total benefit" in the long run.

***TP4.1.** A Survey of Practical Applications of Network Analysis, DANIEL J. KLEITMAN.

A number of practical problems involving synthesis or analysis of networks are described. These problems provide opportunities for applications of computer oriented

mathematical techniques. Some recent successful applications of such techniques to problems of this kind are reviewed.

*TP4.2. Maximally Connected Subgraphs of a Graph, DAVID W. MATULA.

A largest subgraph of edge-connectivity k of a graph G is termed a k-component of G. The total number of subgraphs of a graph which can be k-components for some k is no greater than one-half the order of G. Utilizing network flow techniques an efficient procedure for determining the k-components of G for all k is presented. The theory readily extends to capacitated networks providing an algorithm for determining the subnetworks of greatest capacity.

*TP4.3. Equitable Colorations of a Graph and a Type of Scheduling Problem, D. DE WERRA.

We consider the following kind of scheduling problem: a set U of jobs is given; each job u is characterized by an agent and a machine. All individual completion times of the jobs are the same. The problem is to find a partition of U into a given number k of periods such that: a) the total completion time l is as small as possible, b) each agent (and each machine) is working approximately the same amount of time during each period. A graph-theoretical model is given for this problem and a simple algorithm for constructing a schedule satisfying constraints a) and b) is outlined. Finally some applications are described.

*TP4.4. All Shortest Distances in Large Serial Networks, JOHN M. BURT, JR.

This paper describes an algorithm for computing the shortest distances between all pairs of nodes in certain large networks. For highly "serial" networks, i.e., those containing a substantial number of nodes connected to exactly two other nodes, the procedure is considerably more efficient than the traditional cascade algorithm-decomposition method. These improvements (often a degree of magnitude or more) are achieved by combining a path-following procedure with the cascade method. Empirical results are given of an application of the algorithm to an urban transportation network containing 357 nodes.

TP4.5. On the Efficiencies of Algorithms for Detecting Negative Loops in Networks, JIN Y. YEN.

The algorithms that detect negative loops in a network have wide applications in solving a variety of operations research problems. The purpose of this paper is to examine the efficiencies of some of the most efficient algorithms presently available for solving the problem—namely, the algorithms proposed by Floyd (1962), Dantzig (1966), Dantzig, Blattner, and Rao (1966) and Yen (1970). The efficiencies of these algorithms are first examined by their theoretical computational bounds. This is followed by an empirical study in which the different algorithms are applied on random data. Some findings in this study are contradictory to the assertions made by many other authors in related fields.

TP4.6. A New Method for Cost-Duration Analysis in Project Networks, E. J. DUNNE and M. I. DESSOUKY.

The paper presents a new approach for determining cost-duration relationships in project networks based upon the concept of proper oriented cut-sets (POCS's). The approach uses the fact that a minimum set of arcs (not necessarily distinct) whose reduction by one unit results in the reduction of the total project by n units may be arranged to form n POCS's. The procedure, now computerized, selects at every step a set of arcs such that their addition to an existing minimum-cost set of n minus one POC's will constitute the minimum-cost set of n POC's. Complete proofs are given.

*TP5.1. A Statistical Analysis of Traffic Control Strategies, PREM K. MUNJAL.

Present traffic signal control strategies deal almost exclusively with deterministic traffic character. From a statistical point of view, vehicles approaching an isolated

intersection or moving in a traffic network represent a periodic stochastic process. Therefore, a statistical analysis is necessary to examine the influence of randomness on different control strategies. In this paper we begin by describing briefly the various present-day traffic control strategies, and subsequently study the fluctuations according to certain mean square error criteria. This statistical analysis is then extended to evaluate the diamond interchange signal control strategies and is supported by the field-validated simulation model.

*TP5.2. On Selecting Statistical Data Analysis Techniques for Space Station Applications, PATRICK L. ODELL.

The proposed space station is to be a national laboratory in which a large number of scientists representing a large number of scientific disciplines are to perform their respective experiments. The laboratory equipment requirements are effected by a spectrum of factors including the experiments to be performed, the type of data to be collected, the experimental design selected, and the technique to reduce the data. The paper discusses the potential effect on equipment requirements by considering alternative data analysis techniques.

*TP5.3. An Information-Theoretic Approach to Stimulus Sampling: A Cross-Cultural Analysis, JEROME B. KERNAN and LAWRENCE L. SCHKADE.

Decision environments often contain considerably more information than can be "searched" realistically. The quantity of information transmitted was viewed as the amount of information that was decoded properly, where a degree of relationship occurs between input and correctly-interpreted output. This relationship was assessed experimentally through alternative revisions of the Shannon-Weaver information-theoretic measure in the analysis of search patterns of Mexican and North American subjects. Both the "power" and "efficiency" of the environmental search heuristics of subjects were determined. Significant differences in search behaviors were observed, and these were examined for relationships to individual and cultural influences.

TP5.4. An Empirical Bayes Estimator for the Scale Parameter of the Two-Parameter Weibull Distribution, G. KEMBLE BENNETT.

An empirical Bayes estimator is given for the scale parameter in the two-parameter Weibull distribution. The scale parameter is assumed to vary randomly throughout a sequence of experiments according to a common but unknown prior distribution. The shape parameter is assumed to be known; however, it may be different in each experiment. The estimator is obtained by means of a continuous approximation to the unknown prior density function. Results from Monte Carlo simulation are reported which show that the estimator has smaller mean-squared errors than the usual maximum-likelihood estimator.

TP5.5. Bayesian Sequential Multi-Decision Data Collection, NORMAN H. NOE and S. EHRENFELD.

A formal Bayesian framework is provided for the problem where some possibly contaminated data item can be collected periodically and where additional information about each period's true data value can be obtained at some cost. A decision is made each period with loss depending on the true data value and the decision. The special case with normal distributions and quadratic loss is formulated as a dynamic programming problem and results include proof that the optimum policy structure calls for a more expensive form of data collection initially with less expensive data collection after the process parameters are better known.

*TP6.1. Managing the Environment, WALTER R. LYNN.

The public policy issues associated with management of the environment are discussed and the role of operations research in providing information for this class of management decisions is examined. The special properties of this class of problem are

illustrated in examples from population biology, epidemiology and human population control.

*TP6.2. Mathematical Models for the Control of Growing Biological Populations: A Survey, DAVID L. JAQUETTE.

Recently theoretical and practical research effort has been directed to the control and also to the optimal control of growing populations. Deterministic and stochastic population models of biology serve as the basis for application of the system's analysis and control theory approach of OR to find optimal or at least efficient control strategies for ecological management. Applications of this methodology have been made to finding controlling strategies for varied biological populations.

In this paper, the current "state of the art" is examined, and the contributions to and future challenges in this field are surveyed. A bibliography is included.

*TP6.3. A Survey of Mathematical Application to Water Pollution Control, ANDREW WHINSTON and GLENN GRAVES.

The paper will provide a survey of recent attempts to apply mathematical techniques to the solution of water pollution problems. First we will present a framework for analyzing the role of quantitative modelling in the solution of the entire environmental problem. Next we shall give several of the current models and evaluate them both from a theoretical viewpoint and secondly on their potential for contributing to the actual solution of some real problem. Finally we will attempt to assess the future uses of mathematical models.

*TP6.4. Ecological Simulations: Biospheric Operations Research and the Carbon Cycle, JERRY S. OLSON.

Organic carbon production by green plants has been at least that released by animals and microorganisms over history. Man has reversed this trend by forest clearing, and by accelerating the burning of fossil fuels. Depending on parameters under study in biome projects of the International Biological Program, simulations should help to explore maximum production of suitable mixtures of food and other renewable resources integrated over long periods. Imposed constraints of acceptable "environmental quality" may require significant changes in national and international policy regarding forest and land management, and the scheduling of nuclear and conventional power generation in the next decades.

*TP6.5 A System for the Stochastic Simulation of Even-Aged Forest Stands of Pure Species Composition, PETER E. DRESS.

A general computational system has been developed for the simulation of even-aged forest stands of pure species composition. This system consists of four major linked segments: 1) control and input/output; 2) stand generation; 3) assessment of elemental competitive environment; and 4) stand dynamics for the simulation of growth and mortality processes.

The control section provides for flexibility on the basis of externally supplied information. The stand generation segment permits as a starting point for simulation one of three types of initial stands. Segments three and four are designed frameworks that describe the various processes involved in competition, growth and mortality.

TP7.1. Projection of Student Enrollment by a Two-Step Markovian Process, WARREN R. HARDEN and MIKE T. TCHENG.

Markovian models for the projection of student enrollment have been previously suggested. In application, difficulties arise when (1) the numbers of University departments and consequent states increase, and (2) the projected enrollments of various fields exceed the maximum enrollments established by various departments. This paper introduces a two-step Markovian model which resolves the difficulties, and describes the authors' experiences in utilizing the developed model at Illinois State University.

TP7.2. Risk Simulation for a Proposed Plant Location, THOMAS L. HONEYCUTT.

The objectives of this study were to measure the profitability of an investment in a processing plant and to assess the amount of uncertainty or risk inherent in the profitability estimate through a simulation study. The profitability index used was discounted rate of return or interest rate of return. Subjective estimates for the lowest, highest, and most likely values for each key variable were used to calculate unique beta distributions. Confidence levels on the most likely estimates were also used in calculating betas A beta variate generator and an algorithm for rapid calculation of interest rates of return were developed.

TP7.3 A Cost-Effectiveness Approach to Staff Assignment, YING C. CHUANG, and FUN KUN TSAI.

Modern educational systems are becoming increasingly larger and more complex. This large complex educational system, functioning in a highly integrated and interdependent manner to achieve an overall performance and cost, is a critical problem. A quantitative approach, in place of intuitive judgement, may be required to allocate optimally the personnel resources in the modern large complex educational system. A model of staff assignment in the cost-effectiveness approach has been designed and its use in the New York City School System is being proposed. This paper will present and illustrate the assignment model and some of the implication for implementing it.

TP7.4. The U. S. Naval Weapons Laboratory Minehunting Model, JOHN L. BAILEY.

The purpose of the minehunting model is to evaluate the effectiveness of underwater minefields when countered by minehunting. The model simulates a minehunting operation, taking into account duration, sonar, number of ships, traffic, water and bottom conditions, types of mines and type of neutralization procedure. Random numbers and probabilities are used to simulate events so that in the long run detections, neutralizations, actuations and damage will realistically simulate an actual operation. The Naval Mine Forces will use this in conjunction with minesweeping, minelaying, and minefield planning models developed at NWL to help plan minefields and to plan countermeasure strategies.

TP7.5. The Dynamic Assessment of Risk, MICHAEL A. LEONE.

Recent cost growth in large government programs has generated increasing concern to both the defense contractor as well as the government. This concern has manifested itself in a requirement for a more precise assessment of the risk associated with each program objective. This paper develops a predictive model that can be used to assess the magnitude of the risk associated with various design alternatives. This assessment is periodically updated at major decision milestones in the development process to provide management with the maximum visibility at each decision.

TP7.6. Dynamic Optimization of Pollutants of Multiproducts of Multifirms, S. BASHEER AHMED.

It is the purpose of this paper to present a general theoretical model for pollution minimization of multicommodity for multiplants The objective of the model is to find the efficient production technology which minimizes the total pollution. The state of the system is described by the level of production and the amount of pollution. The decision variables are defined as 1) the penalty per unit of pollution and 2) the subsidy to the consumer of pollutants. Dynamic programming is used as an optimization technique.

TP7.7. Use of Simulation and Optimization in Texas Water Planning, W. L. MEIER, JR. and ARDEN O. WEISS.

Much has been written about the need to apply operations research techniques in water resources planning and management. A number of researchers have made limited applications in the past. This paper describes the application of network optimization techniques and simulation in the analysis of an actual water planning problem involving collection and reregulation reservoirs, massive canals, and pumping stations. The total

cost of the proposed system was projected to be in excess of 10 billion dollars. Through the application of simulation and optimization this cost was reduced by approximately 20%. Computational experience and opportunities for future work will be presented.

TP7.8. Cost, Effectiveness and Patient Care, DANIEL HOWLAND.

Operations Research and Systems Analysis are being proposed for the solution of problems resulting from increasing costs and demands for health services. Difficulties are being encountered, however, in the application of these techniques. One reason for this may be that the models which are used for analysis are not sufficiently descriptive of the systems for which decisions are being made. As an alternative, health care delivery systems are being viewed as adaptive organizations and cybernetic models are being used to describe them. The research leading to the development, test and use of a cybernetic model is discussed.

TP7.9. A Multi-Channel Communication System, PAUL R. MILCH.

A multi-channel sattelite communication system is used by a fixed number of customers to transmit coded, formated messages to a control center. All messages must be received by the control center within a critical time interval. Customers select channels at random, but interference may occur because of the overlapping of transmission times of two or more customers on the same channel. This will cause undesirable retransmission delays. The probability of non-interference is computed. A more complicated model is also considered when customers whose message was not received on first transmission because of interference return for retransmission.

TP7.10. Highway and Transit Capacity Additions to Urban Transportation Networks, OMER SAATÇIOĞLU, ALBERT G. HOLZMAN and WILLIAM L. GARRISON.

A mathematical programming model for evaluation and selection of single alternative but interrelated development projects in urban transportation is developed. It is applied to road and transit improvement alternatives. Each link in the transportation network has three types of flow: free flow, congested flow, and transit flow. A disbenefit factor is estimated for each type of flow. Disbenefits are estimated by multiplying the travel times by their corresponding monetary equivalences. In terms of the link-chain-node network representation, a road improvement corresponds to adding new capacity to a link; transit system development corresponds to adding a chain. The evaluation process is performed from both the users' and the decision makers' points of view. It is assumed that users attempt to minimize their total disbenefit in selecting the routes and modes of transportation. Decision-makers evaluate the investment projects based on the minimum total construction cost of proposed projects subject to constraints.

TP7.11. Minimum Cost Equipment Selection for Distribution Warehouses, PAUL S. JONES.

Extensions to existing theory on tandem, single server, finite queuing systems were developed using simulation models. The investigation included networks of multi-server, finite queuing systems with both deterministic and stochastic units of throughput. Three stage tandem networks and six stage converging branch networks were studied. Results were presented for a variety of numbers of servers, service time distributions, and interstage queue capacities. Conclusions were drawn regarding sets of queuing system parameters that maximize throughput. The results were applied to the problem of least cost equipment selection for a broad class of warehousing applications with specific results for dry grocery warehouses.

TP7.12. Manpower Scheduling Decision Rules for a Single Post Office, L. J. KRAJEWSKI and L. P. RITZMAN.

This paper deals with manpower scheduling decisions in a single post office. These decisions are complicated by the extreme seasonal and hourly fluctuations of mail

arrivals. The objective of this study is to show how to derive decision rules which provide the desired trade-off between production costs and mail transit times. These rules are derived deterministically with mathematical programming techniques and then tested under stochastic conditions with a GPSS/360 simulation model. The decision rules, which can be applied easily, prescribe how to change dynamically the overtime usages, manpower allocations to nine different work centers, and work sequences.

TP7.13. The Minimum Covering Sphere Problem, D. JACK ELZINGA and DONALD W. HEARN.

The minimum covering sphere problem is that of finding the sphere of smallest radius which encloses a set of points in E^n. It is shown that the Wolfe dual is equivalent to a particular quadratic programming problem and that converse duality holds. A finite algorithm, based on the Simplex method of quadratic programming, is developed for which computer storage requirements are independent of the number of points and computing time is linear in the number of points.

TP7.14. Optimal Strategies for Capacity Expansion, AVADHESH K. NIGAM.

Given a certain increasing demand function for a product and the costs of operating processing plants of different sizes, the problem is to find the optimal size of the plants to be established and their optimal installation times in order that the present value of all future costs incurred is minimized. The processing cost rate has fixed costs which are proportional to the capacity and variable costs which reflect the economies of scale. Analytic results are derived under different demand conditions when capacity expansion is initiated by means of a separate plant of a given size.

TP7.15. Analysis of Production and Inventory Systems with Stochastic Behavior, JON T. MILLER.

This paper treats the problem of designing production-inventory systems using analog simulation and the adjoint method of analysis. Examples of basic systems are presented. By using the adjoint method, the problem of stochastic demand and other characteristics is simplified and made practical. The examples illustrate this feature. The practical application of the methods presented is stressed.

TP7.16. A Multi-Objective Scheduling Problem with Uncertain Demand, DAVID SAVIR.

A problem in the scheduling of a manufacturing process is interpreted as a general linear model. A vector of objective function is defined, associated with the desire simultaneously to minimize cost and to maximize the probability of satisfying an uncertain demand. The set of optimal feasible solutions to the general linear model is characterized. The simplex algorithm can be used to produce an element of this set. Given assumptions of preference on the set of optimal feasible solutions an algorithm is presented which will produce the most preferred optimal feasible solution.

TP7.17 A Scheduling Procedure to Optimize a Dynamic Natural Energy System, RICHARD D. HAYNES, JACK BYRD, JR., and LEO A. SCHRIDER.

As the demand for coal, oil and natural gas increases, it becomes imperative that areas which contain these limited resources be used in such a manner as to realize the maximum possible energy. When oil and natural gas wells are in the same area as coal mines, decisions must be made as to the time sequence in which energy resources will be withdrawn. By use of energy decline curves, coal areas can be evaluated for their potential energy output. Using these dynamic energy inputs, a revised branch and bound algorithm was developed to schedule the path of mining which maximizes total energy output.

TP7.18. Interpretation of the Air Traffic Control Beacon System Operation as a Queuing Process with Zero Length Queue, EDWIN M. GOLDBERG.

The operation of an *n*-interrogator-single transponder system is identified as a queuing process with the role of the customer being played by an interrogator and the transponder functioning as the servicing facility. In particular, the fact that interrogations which are not serviced (i.e., which do not elicit a reply from the transponder) are, in effect, annihilated further characterizes this queuing process as being one of zero length queue.

TP8.1. A Dynamic Programming Approach to Competitive Alternate Bidding, MICHAEL DEVINE and HILLEL KUMIN.

This paper considers the problem of making a multiple award decision when the total demand for an item is known. Bidders are presented alternate quantities, up to and including the total demand, and they may submit bids at any or all of the alternate quantities. In addition, each bidder submits his maximum production capacity for the item bid upon. The problem is to choose that mix of bidders which meets the demand at the least cost and at the same time meets the maximum production capability. A dynamic programming formulation is shown to be very efficient computationally.

TP8.2. Can Educational Achievement be Predicted? ROBERT GRAUER and STUART DEUTSCH.

Much has been said about what affects the scholastic performance of a child, but little has been done to analytically model it. In this paper, data from 130 Long Island school districts are analyzed to determine if and how educational progress can be predicted. The authors consider both social and economic parameters in developing a multiple response model that forecasts student achievement. The systems under consideration are the elementary, junior, and senior high schools.

TP8.3. Mathematical Model Design and Reliability Analysis of a Weapon Control System, RUDOLPH ALLAN BULMANN and CHARLES R. WHITE.

A method for designing a mathematical model for a weapon control system, a general data analysis program to determine the reliability functions of every major unit (black box) within the weapon control system, and a general computer model for the reliability analysis of a weapon control system were developed. The concepts were illustrated by designing a mathematical model, determining the reliability functions of every unit, and determining the operational reliability of the MG-13 weapon control system, which is incorporated in the F101B all-weather interceptor.

TP8.4. Technological Assessment: Societal and Environmental Parameters, J. N. FOX.

Technological developments invariably affect some people or interests beneficially and others adversely. We have not successfully derived precise quantitative techniques which evaluate the benefits and the burdens which are needed to arrive at a net index of social desirability. There are a great number of values other than economic efficiency, but most attempts to compute a net social benefit have been useful only as a rough first approach. Also, the burden of uncertainty historically has tended to fall on those who challenge a technological trend, especially when the consequences can only be surmised and when its costs and/or benefits have not been clearly assessed. Technology holds great promise for our future, as well as great peril. Methods of assessment of technology need improvement in order to bring broad social, political, and environmental considerations into focus as well as the economic factors.

TP8.5. Optimal Issuing Policies for a Perishable Inventory under Stochastic Demands and Uncertain Consumption, WILLIAM P. PIERSKALLA

The problem considered in this paper is to determine the optimal issuing policy which minimizes the expected number of outdates for a given supply and stochastic demands, where the conditional probability that a unit of age i issued to demand class j

will outdate because it is not used is positive for most i and j. In the deterministic case this problem reduces to the series of transportation problems; the solution of each problem yields the resource vector of the next. Corresponding results hold in the stochastic case.

TP8.6. An Algorithm for the Plant Location Problem, R. L. BULFIN and V. E. UNGER.

The problem considered involves the selection of a subset of plants to be opened from a set of possible plant locations. Each plant has an upper bound on its capacity. Fixed costs are associated with opening a plant and variable costs with transporting units from the plant to the market areas. The subset of plants is to be selected such that the total cost of satisfying customer demands is minimized.

By applying Bender's partitioning procedure the problem can be partitioned into an integer programming problem and an associated network problem. A solution technique combining an implicit enumeration approach with the out-of-kilter algorithm has been developed. Computational experience is being obtained.

TP8.7. The Bottleneck Transportation Problem, R. S. GARFINKEL and M. R. RAO.

The bottleneck transportation problem is a variation of the Hitchcock transportation problem where the maximum cost corresponding to positive flow is to be minimized. In addition, one may wish to find from among all optimal solutions to the bottleneck transportation problem, a solution which minimizes a linear function of the flow through the bottleneck arcs. Two algorithms are given for solving these problems. One of them is a primal approach and the other is a "threshold" algorithm. Both methods are tested on the computer. The "threshold" algorithm is found to be far superior.

TP8.8. Characteristics of Constant-Speed Recirculating Conveyors with Markovian Loading and Services, LYNN E. BUSSEY and M. PALMER TERRELL.

The existence and significant effects of finite time delays, introduced by constant conveyor speed, discrete load spacings, and finite distances on the design of constant-speed recirculating conveyor systems are developed and explained. Operating characteristics recognizing these finite delays are presented. Analysis indicates that direct application of multichannel queueing theory, assuming zero time delays between certain points in the system, is inappropriate for the design analysis of such systems, and indicates that many operating characteristics reported in previous investigations utilizing this assumption appear to be invalid for randomly loaded and serviced constant-speed conveyor supplied systems.

TP8.9. Applications of Mathematical Programming to Computer Science, ALAN C. WHEELER

This paper presents several examples of problems in computer science to which the techniques of mathematical programming may be applied.

TP8.10. Computational Aspects of the Multi-Commodity Production Planning Problem, PAUL R. KLEINDORFER.

This paper studies the multi-commodity production planning problem with quadratic costs. Utilizing programming solution of the associated discrete-time optimal control problem yields linear decision rules for the decision variables. The special cost structure of the multi-commodity production planning problem is used in conjunction with results characterizing the asymptotic linear decision rules to derive computational solutions for large problems. Applications to production and employment smoothing in a multi-stage, multi-product planning problem are given.

TP8.11. Alternatives to Dynamic Programming for Dynamic Lotsizes, ADOLF DIEGEL.

Dynamic programming gives perfect solutions for economic lotsizes if all decision parameters are perfectly known. As such it is invaluable to determine the value of perfect information. But its application utility is limited because it presupposes a definite planning horizon and perfect forecasts for demand, leadtimes, and costs. It breaks down if any one of these parameters is only imperfectly known. That is, Dynamic Programming decisions based on imperfect information on the whole cost as much as the simpler decision procedures described in this paper. These utilize a linear assessment of future demand to fix both order times and order points. They turn out to do nearly as well as Dynamic Programming also for perfect information about any type of demand function.

TP8.12. Maximal Funnel-Node Flow in an Undirected Network, DUANE D. MILLER and JOHN J. JARVIS.

A single commodity network flow which is required to pass through a specified internal node is defined to be a funnel-node flow. An algorithm is presented which determines a maximal funnel-node flow pattern in an undirected network. The algorithm requires four applications of Ford and Fulkerson's single commodity maximal flow algorithm.

TP8.13. Geometric Programming via a Primal Auxiliary Problem, G. V. REKLAITIS and D. J. WILDE.

This paper suggests computational schemes for Geometric Programs with high "degrees of difficulty" based on an auxiliary problem which is the reduced equivalent of the primal problem. The auxiliary problem is derived from the primal program by algebraic transformations and matrix manipulations and has a highly simplified separable structure. Three computational schemes exploiting this structure are discussed, (i) an approach using the techniques of Separable Programming; (ii) an approach using a successive approximation scheme based on the geometric mean inequality; (iii) a method using the Differential Algorithm or local linearization. Methods (i) and (ii) can accommodate Generalized Polynomials.

TP8.14. Cost-Benefit Study of Computerized Regional Blood Inventory System, K. KENDALL, C. C. PEGELS and J. P. SEAGLE.

A cost benefit study is reported for an implemented modular computer system in time sharing mode that controls the inventory of blood in several counties. Various surrogates are used for benefits that are difficult to measure in dollars. The system was installed in a step-wise fashion, and a priori estimates of the stochastic costs and benefits were made for each step and compared with observed costs in order to evaluate the estimation techniques. Unexpected external benefits and costs were observed. The study has important implications for information system adoption decisions in the public and institutional field.

TP8.15. Cost Sensitivity Analysis for a Radiology Planning Problem, G. J. THUESEN, and W. G. SULLIVAN.

The problem of how best to distribute radiographic facilities in the master plan of a large teaching hospital has not been systematically investigated and reported in the literature. An economic evaluation methodology has been developed for this particular type of planning problem. Economic trade-offs between costs of building construction, X-ray equipment, personnel and other relevant factors have been established for various radiographic configurations for a large teaching hospital. The objective of this presentation is to describe the evaluation methodology and to present results of sensitivity analysis which have been performed on various inputs to the model.

TP8.16. Potential Indicators of Efficiency and Effectiveness for the Susquehanna River Basin Plan in Pennsylvania, CHARLES G. JACKSON.

A federal and state interagency Coordinating Committee and Plan Formulation Workshop have evolved a Type II plan over the past seven years and have projected it over the next fifty years to 2020. The paper attempts to relate the demographic, political and economic needs and demands of the thirty counties which are completely or primarily in the Pennsylvania portion of the basin to multipurposed goals and objectives of water supply (including low flow augmentation and flood plain management), recreation, irrigation, and water quality to crude indicators which should check both efficiency and effectiveness of the plan's development in two year increments.

TP8.17 Simulating Forest Fire and Its Control, JAMES B. DAVIS.

Fire has a profound effect on the ecology of the Nation's 1.1 billion acres of forested land. Approximately 4½ million acres of these lands are burned each year. Destruction of watersheds and particulate discharge into the atmosphere have an adverse environmental effect far beyond forest boundaries. To improve fire control effectiveness, the U. S. Forest Service is developing a large scale computer simulation model of the total forest fire control process including fire occurrence and behavior, and prevention, detection, and suppression efforts including integration of ground and air attack. A preliminary version based on the Tonto National Forest in Arizona and operable on an IBM System/360 Model 91 computer is described.

TP8.18. Closed-Cycle Urban Waste Treatment Systems, D. B. DAHM.

This paper reports on work performed at Cornell Aeronautical Laboratory on the development of new concepts for solid and sewage waste treatment for urban areas. Experiments have been performed on the manufacture of activated carbon from sewage sludge and the use of these and other materials in a sintering process. The underlying idea is that the agglomeration of wastes will help alleviate major urban problems in waste disposal. The paper presents the preliminary results of an analysis of a proposed system concept which utilizes municipal and industrial solid refuse and sewage to produce clean water, building aggretage, and sintered ores.

TP8.19. Evaluation of Data Bases, EDWARD T. O'NEILL.

Much effort has been devoted to the technology of information retrieval but relatively little consideration has been given to developing suitable methods of evaluating the adequacy of the data bases. No data base of finite size can contain all materials relevant to a particular group of users. Recent developments in usage models based on Bradford's scattering concepts provide a powerful means of evaluating the comprehensiveness of data bases. Combined with appropriate selection procedures, these models can be used to determine the minimum size data base which would be required to provide a given level of comprehensiveness.

TP8.20. R&D of a Dynamic, Urban, Information System, ROBERT E. SHANNON, RICHARD M. WYSKIDA and JAMES P. IGNIZIO.

The most glaring problem faced by governmental decision makers when trying to deal with urban problems, is the fragmented, incomplete information available to them about the nature and magnitude of the problems. This frequently leads to guessing, emotion, low-grade politics, and waste. This paper reports the progress of one city in developing a dynamic urban information system for continuous gathering and analysis of information about the trends of activities, attitudes and concerns of the citizens. The system being developed is intended to provide quick feedback on actions and changes made within the community and to provide the framework for establishing realistic community goals and measuring progress towards their achievements.

*FA1.1 Flow-Augmenting Meshings and the Maximal Multi-Commodity Flow Problem, M. BELLMORE and J. P. NETTER.

In a multi-commodity network a flow is said to be a blocking flow if, for each commodity j, all chains from sources s^j to corresponding sink t^j contain at least one saturated arc. We show that a blocking flow is optimal if and only if there does not exist in the network a certain structure which we call a simple flow-augmenting meshing. In addition, we show how to change flow on the simple flow-augmenting meshing so that the total flow is increased. If one adds the restriction that every flow be integral, we show that an integer blocking flow is optimal if and only if there does exist a simple integer flow-augmenting meshing. In addition, we show how to use such a meshing to increase the total integer flow. Several existing algorithms can be shown to be methods of finding flow augmenting meshings. In addition, an extension of these ideas to general linear programs is considered.

*FA1.2. Multi-Stage, Multi-Commodity Network Flows, WILLIAM T. TORRES.

A generalization of the feasibility problem in multi-commodity network flows is presented which may be briefly stated as follows: Determine the minimum number of stages needed to send a sequence of sets of commodity flows prescribed over different stages in a given multi-commodity network. The underlying theory is developed and a method for solving the generalized problem is proposed. Any sequence of sets of commodity flows can be sent through a given multi-commodity network in n stages, provided that n is large enough. The theory discussed in this paper establishes lower and upper bounds on this number and gives necessary and sufficient conditions useful for determining whether or not a solution exists corresponding to an arbitrary value of n.

The set of p-commodity flows feasible for a given multi-commodity network is characterized as a set R in p-dimensional vector space. It is shown that R is a convex polytope—a result which is fundamental to this study. Based on characterizing R by its extreme points, an algorithm is proposed for finding a solution to the generalized problem.

FA1.3. Maximal Flow with Gains Through a Special Network, JOHN J. JARVIS and ANTHONY M. JEZIOR.

The special structure of a directed acyclic network with positive gains is utilized to develop a simple and powerful algorithm for maximal flow with gains. The algorithm is described for maximizing flow into the source or out of the sink. Using the fact that a basic feasible solution consists of a forest, finiteness is achieved by showing that basic feasible solutions can be maintained at each iteration and that the primal objective function strictly increases in finite intervals for this special network.

FA1.4. Algorithm for Bounds on Maximal Dynamic Flows, WILLIAM L. WILKINSON.

Efficient methods exist for determining temporally repeated flows which represent a maximal dynamic flow in a network. In many networks of operational interest, the problem is sufficiently unconstrained so as to admit a wide range of alternative optimal solutions. These alternatives represent an opportunity to entertain secondary criteria in selecting a particular maximal dynamic flow solution. An algorithm will be presented for calculating these alternative optimal flows and some applications will be discussed.

*FA1.5 Euler Tours, Matching, and the Chinese Postman, ELLIS L. JOHNSON.

Algorithms for finding Euler tours and postman tours in a graph will be given. The Chinese Postman problem will be related to the Euler tour problem, the matching problem, the shortest path problem, and the garbage collection problem. The polyhedron and bounds for algorithms will be given.

*FA1.6 Optimum Branching-Systems, JACK EDMONDS

Let G be a network, i.e., directed graph. Let R be a non-empty subset of the nodes of G. A *branching* B in G *rooted at* R is a forest in G such that, for every node v of G,

there is a unique directed path in B (containing no edges, if $v \in R$) which goes from some member of R to v. In other words, B is a collection of disjoint "directed trees" in G, rooted respectively at the members of R, which together contain all the nodes of G. A theory and algorithms are developed for the following problem: For any G having a cost $c(j)$ and an integer capacity $d(j)$ on each edge j of G, and for any indexed set $[R(h)]$, of non-empty subsets $R(h)$ of the nodes of G find, if there is one, a minimum-cost indexed set $[B(h)]$, of branchings $B(h)$, rooted respectively at $R(h)$, which uses edge j at most $d(j)$ times. This material is an application of a theory of intersections of "matroidpolyhedra". There exists a branching-system, $[B(h)]$, as described above, if and only if, for every proper subset S of the nodes of G, the capacity-sum of the edges which go from a node in S to a node not in S is not less than the number of elements h such that $R(h)$ is contained in S.

*FA2.1. Progress and Problems in the Urban Environment, ROBERT PORTER.

The rapid acceleration of environmental pollution, and the potential for further degradation of the environment will be presented. The status of federal programs to prevent further degradation of the environment will be discussed in terms of legislation, organization and resources. The need for concerted action by government, industry and the public to improve the quality of the environment will be emphasized.

*FA2.2. A Comprehensive Approach to Urban Growth and Change, LEO MOLINARO.

Our urban planning and development have been piecemeal and opportunistic, with crash programs and institutional reforms started with little expectation of success, symptoms receiving greater attention than underlying causes, and proposed solutions too small to matter or too utopian to enlist support. A systems alternative is proposed in which life support systems and subsystems become fully operative, costs and benefits are calculated, required public and private actions are described and scheduled, and instruments and capacities for carrying out these actions are devised.

*FA2.3. A Regional Air Pollution Analyses Model, ROBERT M. JIMESON.

A regional air pollution model is presented. The model permits rapid testing of environmental and economic consequences of various regional control strategies and aids in developing effective, low-cost implementation plans. Cost effectiveness and more recent cost-benefit analyses are examined.

*FA2.4. The Environmental Crisis in Power Generation and Possible Future Directions, PETER E. GLASER.

The large-scale use of solar energy is proposed to generate power to meet future requirements and to reduce environmental deterioration and resource exhaustion. The potential for the large scale conversion of solar energy on Earth, in the atmosphere, and in orbit around the Earth is discussed with particular attention to the concept of a satellite solar power station. Considerations are given to the state-of-the-art of solar energy conversion devices, transmission equipment, and a receiving station on Earth.

FA2.5. An Operational Residential Growth Model Developed for and Applied to the South Bend, Indiana Urban Area, JOSEPH W. GUYTON, REZA M. SAFAVIAN, and RONALD D. SCHMIED.

A residential growth model was developed for the South Bend (Indiana) Urban Area Transportation and Land Use Study utilizing a technique by which total residential growth is distributed to planning units based on land available for development, desired density, and accessibility to employment. The model is flexible enough to allow for professional evaluation and adjustment; and, because its input requirements are modest, the model is useful as an analysis tool in the continuing planning process. Although developed for a specific area, the computer programs and procedures are adaptable for wide applications.

FA2.6. An Environmental Screening Model for the Location of Power Generating Facilities, DAVID H. MARKS.

The rapidly advancing pattern of urbanization and population growth in the United States today has as its byproduct an ever increasing demand for electric power. However, due to the environmental effects caused by such power generation, objectives other than economic efficiency must be considered in siting and investment decisions. The authors present a screening model based on a branch and bound technique for choosing site locations and configurations that will meet power demands optimally while satisfying such environmental constraints as water temperature standards.

FA2.7. What We Should All Know About the Airport Noise Problem, INDER K. SUD.

The subject of airport noise is examined from its very basics. The state-of-the-art in measurement and evaluation of the airport noise is presented. A discussion on the legal aspects of the problem points out the need for a mechanism to distribute the "cost" of airport noise to the beneficiaries of the air transportation system. Various approaches to the alleviation of noise in the vicinity of airports are discussed. The paper is intended to be a reconnaissance of the airport noise problem.

***FA3.1.** Mathematical Programming Applications to the P's, M. L. BALINSKI and R. H. COBB.

This talk will present various recent applications of mathematical programming from among subject areas listed in the P's: paints, petroleum, politics, pollution, ports, prisons, public taxes.

***FA3.2.** Sensitivity Analysis in Chemical Thermodynamics, J. H. BIGELOW and N. Z. SHAPIRO.

The problem of finding the equilibrium (or steady-state) composition of a chemical system may be formulated as a constrained extremum problem. One often wishes to compute not only the composition, but also its dependence on the parameters of the system. This sensitivity analysis is done as follows: 1) Convert the problem essentially to a geometric program, to circumvent difficulties which arise from the boundary behavior of the original objective function, 2) Write the Kuhn-Tucker optimality conditions; 3) Apply the Implicit Function Theorem. The resulting derivatives of composition variables with respect to parameters incidentally offer a method for solving the original problem.

***FA3.3.** Vehicle Loading, GLENN W. GRAVES.

A common logistics problem is the partitioning of a large number of deliverable modules among a small number of available vehicles. Associated with each module is an earliest and latest time determined by a schedule of requirements. The objective is to construct the minimal number of loads to satisfy the requirements schedule as well as certain other constraints on weight, compatibility, etc. This problem is viewed as mapping the set of modules into the set of vehicles, and an efficient implicit enumeration scheme is devised. Current experience is discussed in the context of the supply of space operations.

***FA3.4.** A Candle to Saint Jude, or Three Real World Applications of Integer Programming, GENE WOOLSEY.

The author will reflect upon his experience with three real world applications of integer programming models to: (1) A telephone company (Operator Scheduling), (2) A construction company (Cutting Stock for Rebars), and (3) A U.S. Government agency (Capital Budgeting for Research and Development). The painful confrontation between Operations Research theory and actual implementation of these models will be lucidly explored with particular emphasis upon heuristic techniques used in each case for either obtaining good starting solutions or a final solution satisfactory to the customer.

FA3.5. Optimal Plant Location with Concave Costs, RICHARD M. SOLAND.

The following problem is considered: select plant sites from among a given set of sites and choose production and distribution levels to meet known demand at discrete points at minimum cost. The construction and operating cost of each plant is assumed to be a concave function of the total production at that plant, and the distribution cost between each plant and demand point is assumed to be a concave function of the amount shipped. There may be capacity restrictions on the plants. A branch and bound algorithm for identifying an optimal solution is described; it is equivalent to the solution of a finite sequence of transportation problems.

*FA4.1. Managing the Development of a Simulation Model, W. EARL SASSER and R. P. OLSEN.

The object of this study is to develop methodology for introducing simulation into an organization. The research involves a study of existing methods for organizing operations research teams, and a study of the feasibility of using project management techniques as a control mechanism for simulation projects

*FA4.2. Statistical Estimation of Large Numbers of Percentiles in Simulations, P. A. W. LEWIS and A. S. GOODMAN.

Estimates of percentiles of distribution functions, e.g., of a waiting-time distribution studied by simulation, are frequently based on order statistics from a random example of size n. To obtain this sample requires a computer time approximately proportional to n log n, and a block of memory approximately proportional to n. Alternatively estimates based on simple stochastic approximation schemes require times proportional to n and a small, fixed, number of memory locations. This paper treats procedures based on *combinations* of these estimation schemes that are suitable when many percentiles are to be estimated simultaneously.

FA4.3. Application of a GERT Simulator to a Repetitive Hardware Development Type Project, JOSEPH J. MODER, RICHARD A. CLARK, and RAMON S. GOMEZ.

GERT is shown to extend the network logic and capability of PERT/CPM, and to be a tool of considerable utility in systems analysis and design. A repetitive type project for the development of new hardware models is used to explore the potentialities of GERT nomenclature. It is shown that if estimates of time, cost, branching probabilities, etc. can be obtained to describe the network activities, the GERT simulation program provides an effective way to both propose and evaluate changes in management policy.

*FA4.4. Generating Telephone Traffic-Capacity Tables by Simulation, M. M. BUCHNER, JR. and R. V. LANE.

When traffic-capacity tables are generated for telephone systems, simulations must often be employed owing to the unavailability of analytic approaches. The study reported on (1) incorporates the effects of day-to-day variations in offered load, and (2) tables the offered load for specified blocking probabilities. Statistical methods for data analysis are described, and numerical examples illustrate the results.

*FA4.5. Estimating Connectivity in Probabilistic Networks, H. FRANK.

Evaluating network connectivity for large networks is a formidable problem. Because of the combinational nature of this problem, exact analytical approaches are generally intractable. Consequently, one must resort to heuristics or simulation. In this paper, we give a heuristic method to rapidly compute the approximate probability that a network is connected. The method is applicable to networks with as many as several thousand nodes. In addition, the procedure suggests an efficient simulation scheme making use of variance reduction procedures for improving the accuracy of the approximation.

*FA5.1. A Problem in Accelerated Life Testing, NOZER D. SINGPURWALLA.

Estimators of the parameters of the Power Rule Model are obtained by using data from censored sample life tests conducted at each of the k accelerated environments. By slightly amending the functional form of the Power Rule Model, it is possible to obtain estimators that are asymptotically (large k) independent. The asymptotic normality of these estimators is ascertained by examining the shapes of their respective relative likelihood functions. When these estimators are used for predictive purposes, it is shown that they yield a biased estimator of θ_u, the conditional mean life (exponential case) at use. A plausibility interval for θ_u can be obtained from the relative likelihood function, and this can be used as an interval estimate of θ_u.

*FA5.2. Conservative Availability Predictions, J. D. ESARY, and F. PROSCHAN.

A recent experience in comparing several designs for a crucial module in a large system made the authors aware of the value of standard methods for combining reliabilities in determining system performance measures such as point availability, steady state availability, and interval reliability from the corresponding measures for components, when the components fail and are maintained independently. In the same context we consider plausible conditions under which the point availability decreases to steady state availability, making estimates based on the steady state conservative.

*FA5.3. Confidence Interval Estimation of Functions of Binomial Parameters, JEROME R. JOHNSON.

A method for the construction of confidence interval estimates of certain functions of several binomial parameters will be discussed. This method uses the exact multivariate binomial distribution of the attribute test data associated with this problem. This method has been applied to obtaining confidence interval estimates of the reliability of several multicomponent systems using component test data and these results indicate the possibility of obtaining an appreciable reduction in the average length of confidence intervals for a given sample size and confidence coefficient by the use of this method as compared with other methods based on various approximate distributions.

*FA5.4. Maximum Likelihood Estimation of Life-Time Distributions for Different Stopping Rules, L. H. CROW and I. N. SHIMI.

In this paper we consider life test experiments which are truncated after some time T or after some fixed number of items $M(M < \infty)$ have been put on test, whichever occurs first. An item on test is replaced when it fails or after it has been on test for a time $S(S < T)$. Assumptions about the form of the life-time distribution on [O, S] are required Maximum likelihood estimates are considered for the life-time distribution on [O, S] based on data resulting from n such experiments. Life-time distributions considered are: A single-parameter family including exponential and Weibull, a multi-parameter family with increasing failure rate on [O, T] a non-parameter family which includes IFR family

FA5.5. Some Stochastic Age Replacement Problems, B. D. SIVAZLIAN.

At the beginning of successive equal time periods, a decision is made to either keep or replace an equipment whose aging is a random variable id. and ind. distributed from period to period. During each period, an operating cost may be incurred, while at the time of replacement a fixed cost K is experienced. The optimal stationary characteristics of this system are studied for two replacement policies: a) replace the equipment when its age at the end of a period exceeds a level Q; b) replace the equipment when its age at the end of a period exceeds Q or after T periods following its initial acquisition, whichever comes first.

*FA6.1. Decision Criteria in Capital Budgeting, FERDINAND K. LEVY.

The paper investigates the three criteria commonly used in allocating limited funds to capital budgets with respect to their sensitivity to errors in forecasts. The economic

concept of elasticity is the basic device used to compare the measures' relative efficiencies.

*FA6.2. Measuring Performance in the Patient Care Operation of a Hospital, RICHARD C. JELINEK.

This paper describes a methodology for measuring performance of the patient care operation (the nursing function) in terms of both the "quantity" of care rendered and the "quality" of resulting service. It develops a model relating "quantity" to "quality" and establishing the trade-off between the two sets of measures. The model so developed is used to measure performance based simultaneously on "quantity" and "quality." Empirical results from 55 patient units in eight hospitals are presented..

FA6.3. A Quantitative Approach to Analyzing Regional Health Care Systems, RICHARD D. SMALLWOOD.

This paper begins the development of a logical framework for evaluating alternative investments in a regional health care system--with particular emphasis on health care systems in developing countries. The goal is to construct a framework for analyzing the effect on health care indicators of widely different alternative investments such as family planning programs, construction of new facilities, or man-power training programs.

This paper presents such a logical structure and then examines a particular example in which each of the component models in the overall framework is given an explicit mathematical form. This example is used to illustrate the kinds of information that can be obtained from such a formulation of the decision problem.

FA6.4. A Point-Perspective Model for Hospital Reimbursement, LARRY SHUMAN, C. PATRICK HARDWICK, and HARVEY WOLFE.

A mathematical model has been developed for use in determining hospital reimbursement rates by predicting total hospital cost. The model is composed of a set of indices which relate the services provided, educational programs offered, mix and complexity of cases treated and geographic location of the hospital to cost. These indices have been developed by employing psychometric methods to obtain subjective estimates from hospital administrators and physicians in addition to using historical data. Results will be presented from 90 hospitals for a three year period.

FA6.5. Towards a Framework of Health Care Measurement-Medimetrics, ROBERT M. STARK.

The effectiveness of health care modes and the attendant resources combine to form an often ill defined, but keenly perceived, measure of the quality of health care. A methodology is suggested to organize two matrices of health care, *effectiveness* and *resources* into a measure of *quality*. Effectiveness variables relate to the outcome of a treatment mode. Resource variables describe means that are required to achieve designated levels of effectiveness. At present only primitive functional relationships for the quality of health care can be suggested. The emerging subject of health care measurement is termed *Medimetrics*.

FA6.6. A Generalized Cost-Effectiveness Model for the Evaluation of Health Programs, GEORGE W. TORRANCE, WARREN H. THOMAS and DAVID L. SACKETT.

The cost-effectiveness approach to health program evaluation is generalized by combining it with a new morbidity-mortality health index. The index for a particular health state is the utility which society attaches to a day in that state. The index-day can then be viewed as a universal unit of health and the model structured to maximize these units, within the specified constraints. Two techniques are investigated for measuring the utilities; two algorithms are investigated for allocating the resources; and the complete model is tested by applying it to four different programs covering a broad spectrum of the health service field.

FA6.7. A Cost Effectiveness Model for Field Operations of the Western Company, DON R. BEER, ROBERT D. DRYDEN and DAVID L. LEVY.

The Stimulation Division of the Western Company is interested in optimizing its operations. The maximization of profit is considered as the measure of optimization. Two methods to maximize profit are to use more efficient methods of stimulation or to relocate or consolidate the present districts and redistribute the stimulation equipment. Making the assumption that the best operations are being used, attention is directed toward the second method of maximizing profits. The purpose of this report is to develop a computerized model for comparison on a cost profit basis for various combinations of districts and equipment.

FA6.8. Procedures for Testing Proffered Production and Cost Functions, JAMES R. MARSDEN.

This paper presents the initial results of research currently being conducted dealing with the logical considerations of testing procedures, in particular, procedures for testing several differing proffered production and cost functional forms in terms of existence and consistency. The questions considered first are logically prior to the parameter estimation. Satisfactory forms are thus chosen, the parameters estimated, and the results analyzed with a consideration of the effects of variations within chosen bounds of the estimators used. The particular application is concerned with the analysis of least-cost water treatment plants.

FA7.1. Analysis of Probabilistic Networks by Markov Chains, JAMES E. SHAMBLIN.

The use of networks to describe projects which contain alternate paths each having assigned probabilities of realization was described by Pritsker and Happ in the concept of GERT. This paper presents a mode-based network as a model which may be formulated as a Markov chain. The network may then be reduced to a combination single branched activity having an equivalent mean and variance derived from the composite branches of the network. This reduction requires only a basic application of the concepts of Markov chains and statistics and thus broadens the potential band of users.

FA7.2. Dispersion Characteristics on Performance Times for a Combined Manual and Decision Task, MARLIN U. THOMAS.

A combined manual and decision task is considered separable into components X_1, X_2, $\cdots$, X_n, each having some holding time distribution. One component has an input random process, giving rise to the decision, which produces a wave of dispersion throughout the X_i's. The effects of dispersion on these components are investigated under varying input discrete probability functions through an on-line controlled experiment. Three measures of dispersion are considered, (1) entropy, (2) weighted-evidence, and (3) a measure called contrast. For the task used in this study the X_i's were found to be gamma distributed and the degree of statistical independence among them increases with learning.

FA7.3. The Dynamics of Corporate Debt Management, JOHN C. G. BOOT and GEORGE M. FRANKFURTER.

While wide attention has been given in the literature to the question of optimal capital structure of a business enterprise, a less broad but nevertheless important problem deserves full concentration. That is, for a given capital structure, what would be the optimal maturity composition of debt capital? To solve this problem, the cases of certain and uncertain future interest rates are demonstrated. For the non-trivial uncertain future interest rates case the problem is constructed in a quadratic programming framework. The degree of conformity of the market to such a normative strategy is tested with a Random Coefficient Regression Model.

FA7.4. Anti-Ballistic Missile Allocations to Defend Targets with Time Varying Value Structures, GARY E. SWINSON

A solution is presented to the problem of determining optimum anti-ballistic missile allocations to defend a point target whose value decreases monotonically in a predictable manner with time. Attacking and intercepting missiles are uniquely described by reliability related parameters. The solution employs dynamic programming under variable constraints. The solution is extended to the case of one anti-ballistic missile battery defending multiple point targets with predictable monotonically decreasing value structures. Dynamic programming is again the tool used to provide the solution.

FA7.5. Mathematical Medical Diagnosis: A Status Report, D JAMES CROFT.

During the past fifteen years, numerous attempts at mathematical medical diagnosis have been made. This paper reviews these seemingly disjoint efforts and discusses them in terms of their critical features. All works are presented in terms of pattern recognition and classification. A set of criteria for evaluating mathematical diagnostic studies is presented. Past studies are compared to the criteria and found lacking. Results of the author's application of numerous models to empirical data are presented. The practicality of current diagnostic models is evaluated and potential research directions for the near future and the long run are examined.

FA7.6. Air Traffic Controller Performance Effectiveness, DOROTHY L. FINLEY.

The need for air traffic controller performance measurements capable of skill difference discriminations relevant to system performance effectiveness criteria has become increasingly imperative. There is evidence that certain system criterial measures collected under simulated conditions are sensitive to performance differences between experienced controllers. The Bunker-Ramo Corporation is presently evaluating a Carrier Air Traffic Control Center training program for NTDC, using student performance data obtained in both simulated and operational environments. The measurement set will include system level criterial measures. Available results will be discussed in terms of the demonstrated utility of such measures for skill level evaluation.

FA7.7. An Algorithm for Solving Traveling Salesman Problems in Restricted Contexts, ROSS E. SCROGGS, III and ALAN L. THARP

Present methods for obtaining an optimal or near-optimal solution for the general traveling salesman problem are not easily adapted to situations with restricted contexts. This paper describes an algorithm which, although it can be used to solve the general traveling salesman problem, is intended primarily to solve problems in which a) the cities visited have partial ordering restrictions and/or b) some cities are assigned particular positions on the tour. The algorithm has been programmed in PL-1. The computer program requires little advance preparation and little knowledge of the mechanisms of the algorithm.

FA7.8. Surrogated Linear Programming: An Alternative Technique for Solving Linear Programming Problems, JOHN PAUL DITTMAN and GLENN E. STAATS.

Surrogated linear programming is a technique which takes any general linear programming problem and transforms it into an equivalent linear programming problem having only one constraint. That one constraint, the surrogated constraint, is a linear combination of the original problem's constraint set. The procedure then heuristically iterates from one set of surrogate multipliers to another until the solution to the original linear programming problem is found. Computational characteristics of the surrogated procedure indicate that it has great potential for resulting in faster solutions to linear programming problems. In addition, the procedure eliminates the round-off error problem which arises in present linear programming algorithms.

FA7.9. Continuous-Review Deterministic Inventory Models and Optimal Control, JAMES G. TAYLOR.

We solve several continuous-review deterministic inventory models by the theory of optimal control. Concave, linear, and convex production costs are all considered, and we both allow and prohibit stockouts. We show that for both concave and linear production costs, the optimal inventory policy may be determined for very general types of holding costs. In the case of convex production costs and no stockouts, we present a less complex alternative than the analysis of Arrow and Karlin. We discuss the insight provided by these deterministic models in the stochastic case.

FA7.10. A Flexible Enumeration Scheme for Zero-One Programming, LEON B. ELLWEIN.

Each of the main enumerative methods for zero-one programming has a drawback: the branch-and-bound (multi-branch) approach may require an inordinate amount of storage capacity and the backtrack implicit enumeration (single-branch) approach circumvents this storage problem only by restricting the flexibility of the search. A new implicit enumeration scheme is outlined that allows a greater search flexibility (backtracking is no longer mandatory when branching backward) while maintaining a low storage requirement. An example illustrates the method and computational results are presented.

FA7.11. Formulations of the Bussing Problem to Achieve Racial Balance, J. A. WHITE, W. E. BILES, K. E. CASE and P. M. GHARE.

Many metropolitan school districts are faced with the problem of bussing school children in order to achieve a specified racial balance in each school within the district. The costs of achieving the desired balance are quite significant for some districts. In order to bring analysis to bear on this problem, this paper presents mathematical formulations for the "bussing problem." Included in the paper are discussions of the problems associated with determining an appropriate objective function. The criteria examined are those of minimizing the total distance all students travel, minimizing the cost of bussing. Solution procedures are indicated for the various formulations.

FA7.12. Computer Methods for Automatic Diagnosis (COMAD), H. TRAUBOTH.

During the last years, enormous progress in computer technology has been made At the same time, great advances in new mathematical techniques in such disciplines as control systems engineering, information theory, and systems theory have been made. By utilizing the information in dynamic signals at the outputs of a system, knowledge about the state of health of its units inside the system can be derived. This could lead to a reduction of instrumentation and data acquisition hardware for automatic checkout at the expense of more analysis computations in the computer.

FA7.13. The Spatial Distribution of Physicians, RICHARD M. SCHEFFLER.

This paper develops and estimates a multivariate regression model which explains the per capita distribution of physicians in the United States. Aggregate and disaggregate estimates of parameters and elasticities are given yearly from 1956 to 1967. Variables are included which measure, the demand for medical services, the production of physicians, the mobility of physicians, the effect or urbanization and the income of physicians. Policy variables in the model are used to suggest methods of correcting the geographic maldistribution of physicians.

FA7.14. Development and Implementation of a Parking Systems Analysis Framework, RAYMOND H. ELLIS and PAUL R. RASSAM.

Although parking constitutes an important element of urban transportation, related analytical tools remain limited. This paper discusses the development and a prototypical application of a framework for conducting parking systems analysis. Two major elements

are the calibration and validation of component models and their application to evaluate alternative programs.

The Parking Systems Simulation Model (PSSM), which simulates the operation of a parking system for time-dependent demand and supply, is a key element of the proposed framework. The PSSM is based on an allocation model, which, at every cycle, assigns arriving vehicles to available facilities.

FA7.15. O.R. Techniques Relevant to Corporate Planning Function Practices An Investigative Look, FREDERICK C WESTON, JR.

This paper discusses the results of a survey of companies currently constituting the Fortune 1000 (1st 500 and 2nd 500). The purpose of the study was to determine the specific relationships and impact of the newer academic disciplines of operations research and systems analysis to the long-range planning function within large companies The paper discusses how and to what extent corporate planning managers make use of O.R. capabilities. It also discusses, from the viewpoint of the O.R. manager, which services are of greatest demand by the planning manager. An attempt is made to relate the type of O.R. models employed with the: (1) group responsible for constructing these models and (2) the organizational level responsible for model preparation.

FA7.16. Optimal Inventory Policies in Contagious Demand Models, A. RAVINDRAN.

This paper applies the notion of contagious distributions in the inventory control of new products and seasonal-style-goods, which have an underlying true contagion for their demands, namely, the influence of past demands on future occurrence of demands. A contagious distribution is derived by assuming a nonstationary Poisson process where the demand rate any instant depends on the past demands prior to that instant. Using this contagious distribution, an inventory model is developed for seasonal goods and new product lines. Optimal order policies as a function of the initial stock level and the review period are derived.

FA7.17. Convergence Rates for a Method of Centers Algorithm, ROBERT MIFFLIN.

A method of centers algorithm for solving differentiable nonlinear programming problems with strict interiors is presented. The algorithm generates a sequence of feasible points and an associated sequence of multipliers which under pseudo-concavity assumptions have limit points satisfying the Kuhn-Tucker optimality conditions. The feasible points are approximate solutions to unconstrained problems and can be found by finite procedures Under assumptions which imply the problem has a unique non-degenerate Kuhn-Tucker point it is shown that the difference between the optimal and k^{th} objective values and the norm of the difference between the Kuhn-Tucker point and its kth approximation are bounded above by an exponential function of k which converges to zero.

FA7.18. Student Degree Program Management by Simulation, RICHARD F. BARTON.

University resources are usually allocated to degree programs under a given master schedule. Some students may not obtain courses needed to complete degree requirements or may have to take courses out of sequence. In contrast, simulation based on individual student degree programs offers improvement. The master schedule would be the final result rather than the starting point. Inputs to the model are section-size policies, degree programs, faculty, students, space, and personal preference. The model guarantees courses

to students who need them most and assigns all resources based on needs derived from student-by-student simulation of future behavior.

FA7.19. Dynamic Programming and Branch and Bound Approaches for Analyzing Decision Trees in Normal Form, HERBERT MOSKOWITZ.

An efficient method for analyzing decision trees in the normal form is developed through appropriate partitioning and variation in computation sequence. The tree thereby assumes a new form which is analyzed using dynamic programming or branch-and-bound methods applied to vector-valued variables. The set of admissible strategies is found with a significant reduction in computational effort. A trivial linear program, whose solution exists in the objective function, is then formulated by inner linearization. Dealing with the normal form provides maximal information for decision purposes and requires no subjective prior probability assessments for the analysis.

FA8.1. Application of Order Statistics to Decision Making, ROBERT A. BROWN and KENNETH L. RICH.

The authors discuss their research into the application of order statistics to decision making problems. The research includes the structuring of a mathematical model describing the process of project selection from many proposed projects. The authors investigate questions such as the optimum ratio of proposals to projects, allocation of funds between projects and proposals and between different areas of opportunity, and whether the quantity of proposals determines the allocation of funds.

FA8.2. The Traveling Salesman in Time, WAYNE FELTS and PATRICK KROLAK.

This paper describes a problem called the traveling salesman in time (the distances are time-varying). This problem is a model for scheduling the visits of mobile health care teams into rural areas, the scheduling of certain computer job shops, and the scheduling of the visits of a salesman whose expected sales in a given city are a function of the day that he visits. The paper will develop an algorithm that uses both branch and bound and dynamic programming techniques to solve moderate size problems. An example of scheduling various high priority jobs in a multi-programming environment is cited.

FA8.3. A Methodology for the Analysis of Patient-Care System Time Series Behavioral Data, RICHARD A. REID.

A methodology has been developed and evaluated for the analysis of time series behavioral data. The purpose of this interrelated set of procedures is to identify relationships existing between the variables of a system as recorded in the system's performance data. In particular, indications of a system's structure and identification of the sets of variables associated within specified time domains are sought in the analysis procedures. Time series behavioral data collected on an actual patient-care system have been analyzed to test and evaluate these procedures. Preliminary analysis of this data confirms known patient-care system relationships and suggests tentative relationships for further investigation.

FA8.4. A Useful Probability Model Based on an Alternating Renewal Process, MECKINLEY SCOTT.

Most of the birth processes discussed in the literature are assumed to take place under homogeneous conditions. There are many situations in which such conditions do not hold, e.g., automobile accidents occur more frequently in bad weather than in good weather. A probability model is described that deals with cases of this type. Expressions for the various probability generating functions associated with the model are obtained. Some generalizations of the model are also discussed.

FA8.5. Selling Management Science to Management—A Package Approach, RICHARD A. CHASE.

Advances in management science and computer technology are providing powerful techniques for management's use in the planning and decision processes. But where management personnel lack the background necessary to readily understand the concepts involved, efforts to introduce these techniques into the management scheme can be met with distrust and rejection. An approach to overcome this problem and gain acceptance of computer simulation for evaluation of complex alternatives in fire protection planning on the National Forests is described through use of a slide-tape program, portable computer terminal, and time-sharing. The manager is personally involved in a demonstration of how computer simulation works, and acceptance of it is more easily achieved.

FA8.6. Toward a Technique for a More Exhaustive Evaluation of Urban Area Performance. J. W. DICKEY and J. P. BRODERICK.

One of the major aspects of the urban area performance evaluation process receiving little attention to date is that of the exhaustive identification of factors to be considered in evaluation. The object of this paper is to describe a technique useful for making an exhaustive identification and to suggest ways in which the many factors that evolve can be culled and eventually utilized in common evaluation procedures. The technique involves the cross categorization of a set of adjectival antonym pairs, obtained through a *Thesaurus* search, with a set of urban area elements, derived by expanding the Ekistic grid. The categories that result are the evaluation factors to be considered.

FA8.7. An On-Line Natural Language Information Retrieval System for Use by Police Investigative Units, DAVID ALAN BIRD.

A natural language inquiry information retrieval system is presented. This system will accept a relatively free-form English sentence as input, from which essential information is extracted, and construct a formatted inquiry which is used by the search algorithm. The data base for which this system is intended is a police file of known and suspected criminals A typical request sentence might be. "List all white males, approximately 35 years old, who are associated with auto thefts." Record retieval and fact retrieval capabilities are being studied.

FA8.8. A Model for Optimum Water Reallocation Case Study Near Tucson, Arizona, EDWIN DUPNICK and LUCIEN DUCKSTEIN

This paper investigates the problem of water allocation among users and uses which are crucial in semi-arid regions. The model is developed by use of the specific case study of allocation of groundwater between copper mining and the agricultural sector south of Tucson, Arizona. Factors included in the models are: primary-secondary value added, personal income and employment force. The analysis includes: (1) The construction of an economic systems model of individual water users, (2) The interface of that system with a collective utility model, (3) The optimization of the model to maximize benefits over a given horizon using a conjugate gradient techniques with parameter search.

FA8.9. Application of the Delphi Method to the Psychology of Airplane Pilot Eye Movements, FRANCIS J HAINEY.

An account is given of an experiment in the use of the so-called DELPHI method which was developed in order to obtain the most reliable opinion consensus of a group of experts by subjecting them to a series of questionnaires interspersed with controlled opinion feedback. This technique has been applied to the problem of airplane pilot visual search eye movement patterns for effective midair collision avoidance. The opinions of a group of acknowledged experts in the fields of aviation and visual psychology were obtained. A consensus of opinion was reached concerning an effective pilot visual search eye movement pattern. Pilot eye movement recordings taken in flight show a high correlation with experimental results

FA8.10. Application of Differential Sensitivity Analysis for Optimization of Discrete Operations Research Model, S. WAZIRUDDIN.

Multistage operations research problems when formulated for solution by the discrete maximum principle usually result in a set of nonlinear difference equations with initial conditions given at more than one point. Due to the nonlinearity of the system, standard methods for solving linear two point boundary value difference equations cannot be applied. The purpose of this paper is to present an algorithm based on differential sensitivity analysis for solving the above problem. A set of two example problems from the fields of production and advertisement scheduling are solved for purposes of illustration and to test the computational efficiency of the method. Advantages and disadvantages of the algorithm are also discussed.

FA8.11. Estimation of Moments by Quadrature, DAVID H. EVANS.

An underlying problem in setting tolerances in manufacturing, or in determining the roots of equations with random coefficients (e.g., input-output analysis under uncertainty), or in linear programming with random coefficients, or in PERT analysis, etc., can be described as follows. Find the distribution of a random variable X, which may be a vector, when $X = f(Y_1, Y_2, \cdots, Y_n)$ and the Y_i are independent random variables from known distributions and the functional relationship may be known explicitly, implicitly, or experimentally. A numerical quadrature method will be described which gives good estimates of the lower moments of X, thus providing estimates of some probabilities of interest without resort to relatively inefficient Monte Carlo methods for this case.

FA8.12. Programs Management at Hq USAF, WILLIAM GRODOWITZ

The Air Force programs manager serves as the integrater of all resources, i.e., the bridge and synergist between the planner and budgeteer. In today's austere Defense establishment, when its budget is being sharply reduced, the programs manager serves, de facto, as the principal shaper of forces and support in accommodation of a spectrum of budgets. The manner in which Programs Management functions at Hq USAF is analyzed in respect to responsibilities, objectives, modus operandi, difficulties and future outlook. In particular, the problems incident to the current cycling of the Programming, Planning, and Budget System are assessed. Management improvements are suggested.

FA8.13. A Comparison of Bellman's and Howard's Method in Shortest Route Problems, J. P. SAKSENA.

In this paper, a comparison of Bellman's and Howard's method for solving shortest route problems, is made. The same problem has been solved by both methods and the suitability or otherwise of one technique over the other is discussed. In the end, a general summary of the two approaches is presented.

FA8.14. Data Base—The Foundation of Information Structures, ISADORE M. KLAHR.

This tutorial exposition offers a concise argument of the general attributes of a data base, independent of application. All structured information systems share a common subsystem which serves as the foundation for the system. The data bank or data base foundation is the limiting factor for the total system, as the quality of its design has direct consequences on the efficacy of the entire system. The dichotomy between "data" and "information" is discussed along with its relation to data base design and the author's funnel concept of information generation. Several sequels are planned to augment this paper.

FA8.15. Estimating the Economic Benefits of Outdoor Recreation, FRANK J. CESARIO.

This paper discusses a 3-stage model developed for the purpose of estimating the primary economic benefits of outdoor recreation sites (i.e., those benefits accruing to the users). The first stage, the "participation" component, estimates the total number of

recreation trips to be taken in a given region per unit time. The second stage, the "distribution" component, allocates the total number of trips to the recreation sites within the region. The third stage, the "benefits" component, computes primary economic benefits of any existing or proposed site using a "willingness-to-pay" approach.

FA8.16. A Priority Queuing Model for Hospital Operating Rooms, SUSHIL SHARMA.

The paper outlines a method to evaluate queuing characteristics of different classes of patients waiting for surgical care. A non-preemptive priority queuing model is built to analyze waiting times and number of patients waiting in line of each of the priority classes. Use of the model to examine the manpower/equipment requirements is discussed. Comments are made on data collection, seasonal trend of incoming patients and on large-scale implementation. Delay times are compared for different arrival rates of patients and finally suggestions are made on use of the concept in other hospital areas.

FA8.17. An Application of Utility and Decision Theory in a Planning Environment, FREDRICK DAVIDSON.

City and regional planners exist in an environment where they must satisfy numerous contending pressure groups. This paper illustrates an application of utility and decision theory in one such situation: the selection of a "land use plan" for a large area of rural land in a southeastern state. The planning group was required to generate a utility matrix for a set of alternative plans consistent with their perceived heirarchy of needs for the region in question. Subsequently, expected value calculations were used to determine the optimal plan. We conclude by discussing the reliability and sensitivity of this approach.

FA8.18. An Algorithm For Multi-echelon Production Scheduling, JACK F. WILLIAMS.

A very general dynamic programming formulation of the multi-echelon lot size problem, where demand may be stochastic or deterministic, is discussed. A modification is also discussed which, when certain conditions are met, allows the average number of comparisons per state to be reduced from many thousands to less than 50. Costs considered include setup costs, marginal production costs, inventory holding costs, and backlogging or lost sales costs. The probability distribution of demand and the cost functions are allowed to change from period to period.

FA8.19. On Packing A Graph, HENRY D. FRIEDMAN.

A graph is often used to model a communicating organization. The nodes may represent computer modules, communication stations, people, etc. A branch signifies that its endnodes "communicate directly with" each other. Two questions of interest are: (i) What types of constraints yield useful, fruitful models? (ii) Under given constraints, what is the maximum number of nodes that can be packed into a graph? Of special interest are (d,k) graphs for which both the degree d and the diameter k are bounded. These are reviewed, and it is shown that maximal cases called Moore graphs are extremely rare.

FA8.20. Variability of Elemental Times: A Proposed Method for Precedence Diagramming and Analysis in Assembly Line-Balancing, TURKAN E. KUMBARACI.

A method is proposed which, considering the variability of elements in stations of an assembly line, provides a priority index among stations. This index is then used in sequencing stations along the assembly line so that turn-over problems near the end of the assembly line are minimized. The method thus enables the industrial engineer to

collaborate with the design engineer. A check for the engineering feasibility of the method is provided the restrictions of which can be relaxed or tightened.

*FP1.1. Survey of Space Sciences Operations Research, DON N. TURNER.

Previous manned and unmanned space programs have demonstrated the feasibility and potential of utilizing space for the peaceful benefits of all mankind. Now the NASA is engaged in post-Apollo planning which includes such key elements as the Earth-to-orbit Space Shuttle and the large Earth-orbiting Space Station. The Space Shuttle serves as the primary logistics vehicle for the Space Station—a multi-disciplinary research and applications facility. The reasons underlying the program and system objectives and guidelines are presented. Preliminary concepts for crew and mission operations are described and the impact of these elements on the planning function is examined. A typical problem in space sciences operations research is presented and the steps NASA is taking to solve the problem and gain visibility in the area are presented.

*FP1.2. Systems Engineering Challenges of the Reusable Manned Space Shuttle Program, HAROLD E. GARTRELL and ROBERT G. VOSS.

Efforts by the NASA to define and implement a Space Shuttle Program capable of fulfilling national space needs for routine manned operations in earth orbit involve some of the most unique and difficult problems in systems engineering encountered by the space program to date. Not only are the tasks of matching technology requirements and design capabilities with the engineering, manufacturing, and performance requirements a significant challenge, but a new dimension in manned spacecraft development is being pursued in an attempt to minimize cost. This paper presents an indication of some of the results of systems analyses performed on the Space Shuttle system. The Space Shuttle is a NASA program having as its objective the achievement of an economical space transportation system through minimizing operational and development costs.

*FP1.3. Application of Operations Research Techniques for Planning and Analysis of Space Missions and Space Systems, CHARLES P. LLEWELLYN and KAREN D. BRENDER.

The large array of space vehicle concepts, space missions, and research programs in existence today requires extensive analysis and planning to acquire low cost space systems with high reliability and utility. Each of the possible system elements such as Experiment Modules, Earth to Orbit Shuttle, unmanned satellite, Sky Lab, Space Station, Space Base, and others must be studied for possible utility with respect to experiment programs and varying mission duration. Combinations of these system aspects must be analyzed to maximize usefulness and minimize cost. This paper will discuss some current methods being used for total space mission planning ranging from gross manual techniques where detailed data is not available to sophisticated computer simulations for concept and system comparisons.

*FP1.4. Operations Analysis Applied to Space Station Mission Planning, SPENCER A. BULLARD, FRANKLIN L. ADAMS and THOMAS R. HEATON.

The Apollo Telescope Mount (ATM) on the first NASA Skylab Mission will carry solar telescopes to observe in atmospherically obscured spectral regions. During the initial flight, the seventy individual experimental programs require 458 hours observing time which reduces the 130 hours for concurrent operation. The mission plan allows less than 100 hours for ATM. To determine the experiment groups, scheduling procedures, and other critical factors that maximize expected mission accomplishment, a computerized model was developed to simulate the scheduling of ATM experiments under a variety of mission situations and solar conditions. The model has been used to evaluate mission

accomplishment as a function of solar activity, scheduling rules, observing program requirements and other mission parameters. Results of the evaluations are presented.

*FP1.5. Logistics Planning for Phased Programs, JOHN GOODRUM and WARD COOKE.

Development of advanced hardware involves great risk and the greater the degree of technological advancement involved, the greater the uncertainties. The phased approach provides limited technical objectives commensurate with the state-of-art and commitment of funds based on the technical objectives. Programs are normally divided into four sequential phases

a) Preliminary Analysis or Concept Development Phase,
b) Definition or Preliminary Design Phase,
c) Design Phase,
d) Development/Operations Phase.

How program characteristics with special logistics requirements are identified and how they are scoped to phased schedule and technical objectives is discussed. An approach to development of logistics milestones, fitting them to overall program schedules, and assuring implementation is presented.

FP1.6. COMAND—Application to Future Manned Space Vehicles, RICARDO F. GARZIA.

New automatic checkout concepts must be developed for the future manned space vehicle in order to reduce the time for refurbishing and checkout between missions in such a way that the operation cost will be feasible. Through employing fast and efficient fault isolation techniques together with less reliable components, the time for maintenance and the cost could be reduced considerably. The application of the Computer Methods for Automatic Diagnosis Program (COMAD) to the future manned space vehicles is intended to develop a few software methods which are promising for practical implementations.

*FP2.1. The Use of a Medical History Questionnaire in Routing Patients, JOHN F. ROCKART.

In large multi-specialist group medical practices, the problem of reserving time for patients with the correct specialists is typically solved by routing the patient to a single physician who then serves as the "scheduler," selecting other specialists and tests for the patient. Although efficient for the medical institution, this practice is inefficient for the patient, whose waiting time for a diagnosis may be lengthy. This paper reports efforts at the Lahey Clinic to provide patients with a compact schedule of needed specialists based on information received before the visit by means of an automated medical history questionnaire.

*FP2.2. Applications of Simulator-Based Planning Models in Hospital Laboratories, DAVID VALINSKY, MANUS RABINOWITZ and M. BARRY DUMAS.

This paper presents applications of two simulation models developed as aids in planning for more efficient utilization of hospital laboratory services. The first of these is a planning model which allows for the rapid and efficient investigation of varying combinations of human and equipment resources in the clinical microscopy laboratory in terms of three measures of effectiveness. The second model, which simulates the hospital blood bank, was used to evaluate three proposed operating policies for control of blood wastage while using inventory level to control shortages. Event definitions and timing, demand source characterization, decision variables definition, and measures of effectiveness are presented for each of these models.

*FP2.3. Modeling for Incentive Reimbursement, HARVEY WOLFE.

A major thrust has been directed toward the development of equitable incentive systems to be used in conjunction with reimbursing hospitals for services. Most current reimbursement methods used by Blue Cross plans, Medicare, and Medicaid do not

encourage hospitals to keep costs down, in fact, they often provide a bonus to hospitals that permit costs to rise. The application of incentives requires the development of models which can allocate health dollars in an equitable manner to institutions that provide hospital care. Models are developed for estimating target rates upon which incentives can be based. Additional models are derived to reflect an incentive payment schedule which takes into consideration sociological and psychological variables as well as eventual dollar outlay.

FP2.4 On Scheduling the Delivery of Babies, IRWIN W. KABAK.

With the advent of elective induction of labor, the management of an obstetrical practice has assumed the problem of scheduling the delivery of babies. The problem can be thought of as a delay queueing system with a modified finite source arrival pattern. The case of a single server is analyzed to determine the probability of interference (viz. the obstetrician must serve two or more patients simultaneously). The special case of poisson arrivals and gamma (erlangian) service times is solved. Numerical values are presented for these cases. An extension is presented wherein the probability of interference occurring within a finite time is analyzed.

FP2.5 The Sanative Output of a Health Care System, RACHEL ROSSER and VINCENT WATTS.

The work described in this paper is part of a project concerned with the evaluation of a health care system. The main elements of output are defined and approaches to measuring these elements are described. The concept of sanative output, the effect of a system on the health status of the treated population, is developed in detail. This involves the classification of patients' clinical conditions which can be handled numerically on a ratio scale derived from an analysis of court awards in personal injuries cases. Performance indicators are derived by relating the sanative output to costs

*FP2.6. The Evaluation of Income Maintenance Programs, BARTON R. BURKHALTER.

A method for estimating the impact and cost of child allowance programs is reported. Measures such as reduction in the poverty gap, low income gap, and decency gap, as well as the cost of the program are used to evaluate the alternatives Various methods of searching for the most efficient set of programs are used.

*FP3.1. Operations Research for the Federal System of Governments, EDWARD CUSHEN.

In the United States the care of the public good is a responsibility of units of local, state and national governments. There is, thus, a system of governments and not a unitary chain. The nature of the phenomena important to an Operations Research study in the public sector will be pointed out through a series of six short vignettes taken from non-descent contexts. The picture thus developed will be used to make observation on where Operations Research is and probably will be used, and where it should be.

*FP3.2. An Illustrative Analysis: Predicting the Technology and Character of Passenger Travel, 1975–2000, EDWIN I. GOLDING.

The paper is divided into two parts. First a brief description and summary of expected trends in passenger transportation for the next 30 years is given. *A Delphi* exercise is used to predict the probability of technological achievements and R&D cost. Second, a methodology is presented for forecasting at an aggregate level the Modal Split of passenger travel as a function of an individual's value of time, out-of-pocket cost, and trip distance. Response curves showing the probably passenger choice among many technological possibilities at a given trip distance and year are also presented.

*FP3.3. Policy Analysis in the Federal Government, WALTER A HAHN.

The term policy analysis is becoming more fashionable to connote multi-disciplinary substantively oriented work that goes beyond operations research, systems

analysis, and management science to deal with complex quantitative-qualitative "top management" problems, problems involving ill-structured and dynamic situations that are usually broad and long range in nature. While much has been written about the policy or policy analysis *process*, material about the substance of policy is relatively scarce. This paper will present such material, plus observations on the roles of key participants in the process.

*FP3.4. Education for Systems Analysis in Government, ALVIN W. DRAKE.

Many of us came to present interests in public systems from more technical and local concerns with the behavior of complex systems. Recent emphasis on broader issues of "policy analysis" and "public policy" raises many questions about appropriate professional educational programs and career opportunities. To date, for instance, the impact on existing operations research curricula has been relatively small. The speaker will discuss a spectrum of new curricula at several universities and, for better or worse, he will indicate his views on some new directions for undergraduate and graduate education relating operations research and the analysis of public systems.

*FP4.1. On Browsing. The Use of Search Theory in the Search for Information, PHILIP M. MORSE.

Browsing may be defined as a search, hopefully serendipitous In connection with a library, one may browse through the display of recent books to see what is new, or through a portion of the library shelves in the hope of finding a text which may contribute the fact or idea needed in some intellectual effort. Browsing is prevalent in most libraries. In fact, it can be argued that browsing is one of the most frequent ways in which the library user found the book he borrowed. To analyze browsing probabilistically to see whether the browser or the librarian can improve his efficiency, one might try applying the theory of search.

*FP4.2. Cost Effectiveness of Information Transfer Systems, DONALD W. KING.

This paper describes cost/effectiveness methodology developed to assist in design and evaluation of information transfer systems. The overall framework within which cost/effectiveness evaluation takes place is given. This framework consists of seven basic functions found in transfer of information including composition, reproduction, storage, identification, dissemination, assimilation and use of information. Transfer of information from producer (author) to user (reader) involves processes that accomplish a combination of these functions. The cost/effectiveness methodology described in this paper gives measurement criteria and mathematical models for evaluating the cost and performance effectiveness of all the system processes. Examples are given for recently completed evaluation studies using the methodology described in the paper.

*FP4.3. A Stochastic Model of an Information Center, JACK MINKER.

The growth characteristics of information centers are evaluated for retirement policies that govern when items are retired from a primary store of finite capacity to a less accessible store.

A set of integral equations is derived for the expected number of items in the primary store. The integral equations depend only upon the arrival distribution for documents, the request distribution, and the parameters association with the retirement policy. No particular limiting assumptions have been made with respect to the form of the distributions.

The set of integral equations are solved for document arrivals that follow a Poisson distribution.

*FP4.4. Models for the Design of Data Organization, JAMES R. ARSENAULT, J. F. NUNAMAKER JR., and A. B. WHINSTON.

The design of data organization, like much of information processing systems design, has become subject to mathematical treatment. This paper presents a meth-

odology for the design of data organization and discusses some areas for further research. The literature is classified by the design decisions involved in data organization and by solution technique. The design decisions considered involve the specification of data structures, storage structures and resource allocations (e.g., the assignment of files to memory devices). The solution techniques discussed include set theory, graph theory, mathematical programming and simulation. The models and the extent to which they are applicable are discussed.

*FP4.5. The Development of a Statistical Information System for University and Large Public Libraries, MORRIS HAMBURG, MICHAEL R. W BOMMER and LEONARD E. RAMIST.

There has been a long-standing recognition of the need for an improved system of library statistical information. This study is part of a research investigation whose goal is the design and development of a national model for a system of library statistical data for university and large public libraries. The general purpose of the model is to provide a statistical data system which constitutes a comprehensive framework for rational planning and decision making concerning library operations and resources. The system will include the statistical information requirements for a library's own administrative and managerial purposes, and the quantitative information required at other levels as well such as by library associations, legislators, government administrators and funding officers.

*FP4.6. Measures of Effectiveness for a University Library, NORMAN R. BAKER and PHILIP V. RZASA.

Two measures of effectiveness for university libraries are constructed. The Primary Measure of Effectiveness, defined over the total population of users, considers the number of material and information items desired by the users, the number of satisfactorily answered inquiries, and the number of users. For the Secondary Measure of Effectiveness, the total population is classified into subsets according to similarity of user needs. A measure is defined for each subset and is a function of the number of individuals in the subset, the number of actual users in the subset, and the number of repeat uses. An empirical study at Purdue University illustrates that meaningful subsets can be defined and demonstrates that faculty, graduate students, and undergraduate students differ in their reasons for going to the library and in the library materials utilized.

*FP5.1. The Systems Engineering of Education in Operations Research, A. WAYNE WYMORE.

The design of a system whose objective is to provide education in operations research is characteristically the same as any other complex system design project. identification of the client, negotiation of input/output specifications, characterization of all systems satisfying the input/output specifications, negotiation of the technology (universities, communications, computers, teachers, curricula, courses, texts) within which the system is to be implemented, characterization of all systems implementable within the technology, definition of measures of effectiveness, respectively, on the two sets of systems thus characterized, and definitions of partial orders on the ranges, respectively, of the measures of effectiveness.

*FP5.2. Should OR Education be Performance Contracted, RICHARD C. WILSON.

Efforts to plan the future of education for operations research assume that facts about present needs and activities in the profession are available. This paper summarizes the results of a search for such data, and from it draws inferences about the future directions of OR education in universities. Minimal requirements for acceptable curricula in the light of developments in educational technology are proposed.

*FP5.3. OR Education for the Practitioner, FRANK A. TILLMAN.

The emphasis of education programs in Operations Research is not directed toward the practitioner. In practice most of the effort is in defining problems and gathering data.

Little effort is required structuring models since only a few methodologies work in solving actual problems. Among the most useful are statistical analysis, simulation and allocation of resources approaches, particularly linear programming. We should reorient educational programs and professional publications to better prepare the practitioner. He should have a good background in statistical methods, data gathering and evaluation procedures, allocation of resources techniques and the financial operation and requirements of the firm.

*FP5.4. Educational Needs for Operations Research in the Durable Goods Industry, LEONARD R. LAMBERSON.

In manufacturing industries, it is of paramount importance for the O. R. practitioner to be able to sell his ideas to key management personnel. This requires an emphasis on costing, on labor expenditures, and on analysis of the management environment. Also the future of the O. R. practitioner will improve considerably in this environment as the management personnel becomes better acquainted with O. R. techniques. Thus it is important that there be both undergraduate and graduate programs which stress the O. R. approach. The philosophy and contents of both programs will be presented.

*FP6.1. Optimization Theory from the Mathematical Programming Viewpoint, HUBERT HALKIN.

In the last few years a very attractive approach to optimization theory has been promoted by A. Ya Dubovitskii and A. A. Milyutin. The aim of the lecture will be to describe this approach and to report on some recent results which have extended its scope of applications to many area of mathematical programming and optimal control theory.

*FP6.2. Optimality Conditions and Constraint Qualifications, JON W. TOLLE.

The subject of this talk will be necessary optimality conditions for nonlinear programs in Banach spaces and constraint qualifications for their applicability. A new optimality condition will be introduced and a constraint qualification ensuring the validity of this condition given. Under certain assumptions, this optimality condition reduces to the extension of the Kuhn-Tucker conditions to Banach spaces and the constraint qualification is the weakest possible.

FP6.3. Gauss-Seidel Methods in Nonlinear Optimization, DAVID F. SHANNO.

Nonlinear Gauss-Seidel methods are iterative methods for solving nonlinear systems of equations. They solve the system at each step one component at a time, using the updated values for the first K-1 components to compute the Kth component, rather than the values at the previous iterate. These methods can be adapted to nonlinear optimization problems by considering the associated problem of solving the system of equations derived by setting each component of the gradient vector equal to zero. Various forms of this adaptation, with associated computational results, will be documented.

*FP6.4. The Convergence Rates of Some Primal Nonlinear Programming Algorithms, DAVID G. LUENBERGER.

Although the development of algorithms for constrained optimization problems is apparently at a fairly advanced stage, there has been little attention devoted to the analysis of convergence rates associated with the available alforithms. Instead, algorithms are often compared by extensive experiments whose conclusions are rarely definitive. This talk will analyze and compare the convergence rates of three important primal nonlinear programming alforithms: the gradient projection method, the generalized reduced gradient method, and the convex simplex method. It is concluded that the first two have approximately the same rate of convergence while the third is substantially slower.

*FP6.5. New Applications of Duality in Nonlinear Programming, R. TYRELL ROCKAFELLAR.

Conjugate function theory associates with an optimization problem none one, but a multiplicity of dual problems. This flexibility suggests new applications of duality. It is now known, for example, that for a large class of nonlinear problems it is possible to construct duals whose constraints are essentially linear. Duality can often be introduced in such a way that the corresponding Lagrangian problem consists of finding a saddle-point of a differentiable function subject to no constraints whatever (not even nonnegativity). Hopefully, by selecting different dual problems one could reduce the duality gaps encountered in nonconvex programming.

*FP6.6. All Solutions to Linear Complementarity Problems by Implicit Search, C. B. GARCIA and C. E. LEMKE.

The method of making an implicit search of 2^n objects, used with effectiveness in mixed-integer programming, combines naturally with the process of pivoting so as to retain complementary or almost-complementary solutions, to yield a potentially effective technique for recording all solutions to the linear complementarity problem for arbitrary given data. It is expected to be especially of value in solving the general quadratic programming problem, and to finding all equilibria of bimatrix games.

FP6.7. Equilibrium Points in Nonzero-sum n-person Subadditive Games, DONALD M. TOPKIS.

A real valued subadditive function on a lattice is closely related to the classical economic definition of a cost function for systems with complementary products. Considering nonzero-sum n-person games, with a subadditive lower semicontinuous return function, over a compact sublattice, algorithms are presented which generate a sequence of feasible joint decisions. These decisions converge monotonely to an equilibrium point, and the algorithms may be used to find either the greatest or the least equilibrium point. For special cases bounds can be placed on the number of iterations required of each algorithm to find an equilibrium point.

FP7.1. Variable Work Models for Predicting Course Enrollments, K R. BALACHANDRAN, DONALD GERWIN and JOHN AESCHLIMANN.

An important planning problem faced by administration in higher education concerns estimating the student enrollment for courses in the coming semesters. This paper discusses a markov model for predicting course enrollments in future semesters in an integrated graduate program, where most of the courses are required of all students. Basically, course j's demand is the product of a transition probability and the "work" for the course. Work is defined as the number of students involved in the program who have not yet taken the course. The number of dropouts and vacationing students are also predicted and steady state results are derived. The application of the model to an integrated MBA program is discussed. Finally, there is a discussion of some more sophisticated models of this type which require computerized data files on students to be implemented.

FP7.2. Adaptive Forecasting of Weekly Series By A Self-Contained Computer Program, S. P. ZOBEL and R. M. SCAMURRA.

A computer program was developed which tested real data gainst 1331 weight combinations to select automatically the best initial set of weights in a three part exponential smoothing model. From a weekly input of one number, the program provided a report with weekly activity, continually revised forecasts for each of 52 weeks, and two forecast errors. When errors indicated poor forecasting, the weight selection subroutine was automatically recalled, new weights determined, and a revised report printed. Two such efforts may be made before the computer temporarily "gives up". This has been running successfully for several years at a state level.

FP7.3. The Equivalence of Shortest (Longest) Path Problems to Assignment, Covering and Matching Problems, PATANJALI S. NANDA.

In this paper, necessary and sufficient conditions for a personnel assignment problem to be transformed to a shortest path problem are first established. This leads to $2n!n(n-1)$ equivalent shortest path problems in a cyclic network, of which only half lend themselves to a meaningful interpretation. A procedure is developed to solve the equivalent shortest path problems by solving successive problems of reducing size. Necessary and sufficient conditions for transforming generalized covering (matching) problems to shortest (longest) path problems are then established. It is shown how the weighted covering (matching) problem can be transformed to a constrained shortest (longest) path problem

FP7.4. Evaluating Characteristics of Public Transportation Systems in Smaller Urban Areas, KENNETH W. HEATHINGTON, GILBERT T. SATTERLY, and WILLIAM L GRECCO.

Public transportation systems in smaller urban areas have been experiencing economic difficulties for quite some time. Marketing information is needed to insure appropriate operating policy and programs. To obtain this marketing data several characteristics of a public bus system were evaluated for an urban area with a population in excess of 100,000. Specifically, such items as walking distances to bus stops, waiting times, transfers, available seating, etc. were evaluated and priorities were established for design purposes. Various socioeconomic classifications were examined to insure acceptable design criteria for this urban area.

FP7.5. 'Urban Models–Which Way to Go', MYRON R. ROSENTHAL.

We are concerned with models which describe the very complex urban community, the people and the resources. These models have been denoted as land-use, urban dynamics, and socio-economic. What questions are within the scope of these modes? Have these models met their objectives? What is the social value of these objectives–has it been sacrificed for the sake of the model? Can these models be kept current? How are these models being used?

We then propose a model somewhat different in nature from these current models. How will this model fare when exposed to the above questions? An interesting feature of the paper is the examination of the use of urban models as a long-range planning tool in large corporations.

FP7.6. Dynamic Programming and Fuzzy Allocation Processes, AUGUSTINE M. O. ESOGBUE and VENGALATHUR RAMESH.

The modeling and computational aspects of certain allocation processes are studied through a new concept in systems theory–fuzzy decision making. The use of these concepts will generally provide models of better proximity to the systems modelled than the traditional deterministic and stochastic approaches. Some concepts of fuzzy systems theory are first introduced. Fuzzy dynamic programming models with their corresponding flow charts are then provided for an allocation problem arising in R&D systems. The computational problems in fuzzy algorithms are discussed. An extensive bibliography on fuzzy decision theory is included.

FP7.7. A Set Covering Approach to the Web Width Determination, GARY M. ANDREW and MING-TE LU.

Web width determination refers to the problem of determining the widths of the in-process material such as rolls of paper, textiles, plastic, sheet metal and other materials such that a given order of finished product may be cut from those rolls at a minimum cost. In this paper the problem is formulated as a set covering problem. Costs under consideration include trim losses and inventory costs. By solving the set covering problem the optimal web widths under the given assumptions may be obtained.

FP7.8. Towards Cybernetic Loading Models: A Complex Linear Flow Model Approach, FRANCISCO SAGASTI.

This paper presents an approach to the loading problem of production planning and control using the techniques gathered under the name of Complex Linear Flow Models. In particular input/output methodology, Markov chains and linear programming are used to develop a loading model which satisfies the cybernetic principle known as Ashby's Law of Requisite Variety. The steady state or one-period model is developed in detail with examples and an outline for the dynamic or multi-period model is also given

FP7.9. Efficient Heuristic Rules for the Warehouse Location Problem, BASHEER M. KHUMAWALA

This paper discusses a set of efficient heuristic rules for solving a special class of mixed integer programming problems called the warehouse location problem. The heuristic rules are derived from the branch and bound algorithm for the warehouse location problem which was developed in our earlier work. The basis for the heuristics are the branching decision rules used in the branch and bound algorithm. With the use of these heuristics, optimum or near optimum solutions are found by following only along a single branch; thus eliminating the necessity of investigating the entire branch and bound tree. The computational experience on problems found in the literature is presented in this paper.

FP7.10. A Constrained Shortest Path Algorithm, PAUL A. JENSEN and RONALD C. BERRY.

This paper describes an algorithm to be used in solving the shortest path problem for a network whose arcs exhibit, in addition to lengths, requirements on one or more limited resources. The problem is therefore one of finding the shortest path from a given starting node to a given finishing node such that the sum of the resources required by the arcs of the path do not exceed specified limits. The algorithm uses dynamic programming in addition to the concept of dominance, and is demonstrated to be effective for the cyclic as well as the acyclic case.

FP7.11. A Two-Product Inventory Control Model with Substitution, SATISH J. KAMAT.

A two-product inventory system with partial probabilistic substitution of one product for the other when it is out of stock is considered. Retail merchandising has many examples of such systems, usually with more than two products. An order level model with a prescribed order period is used to obtain a cost function. An approximate empirical method of solution is presented, and compared against the solution by enumeration of the above cost function using an example with Poisson distrubuted demands and different levels of average substitution. A generalization to a multi-product system and the difficulties involved are discussed.

FP7.12. A Parameter Perturbation Procedure for Obtaining a Solution to Systems of Nonlinear Equations, J. C. HELM.

For simultaneous nonlinear equations the convergence of the known functional iterative procedures is dependent upon a good initial approximation to the desired roots. In this paper the restriction on the choice of the initial approximation has been circumvented by dividing each problem into a number of subsidiary problems in accordance with a parameter perturbation procedure. The paper presents a discussion of the algorithm and the conditions for convergence. The discussion, also, includes the problems which were solved using the parameter perturbation procedure.

FP7.13. Allocation and Expansion Policies for the Fixed Capacity Resources of a Decentralized Organization, WILLARD N. ANDER

A fundamental problem in any large organizational system is the allocation of resources having fixed capacities in the short run to the various decentralized sub-systems demanding these resources. Peak-load analysis and priority methods are discussed as

possible solutions, and an alternative pricing method utilizing optimal control theory is proposed. The proposed method provides pricing and budgeting policies for allocating the fixed capacity resources in the short run, and expansion policies for controlling the resource capacity levels over the long run. An example is provided which develops resource control policies of a centralized computer facility.

FP7.14. A Monte Carlo Approach to Crew Scheduling, JOHN LOO, BURTON T. O'DONALD and IRVIN R. WHITEMAN

CREATION is the acronym for *CRE*w alloc*ATION*. The program runs on an IBM 360 65 and is used to generate the allocation of crews which man the flights of EASTERN Airlines. The crew allocation problem is representative of a class of problems in which elements of a set are ordered according to some criterion. The problem is marked by factorial growth in terms of the size of the set. Through use of Monte Carlo techniques the program is able to generate least cost solutions to the flight schedule in short periods of time.

FP7.15. Optimal Service Rate Selection in Piecewise Linear Markovian Service Systems, BILL MITCHELL.

This paper considers a single server, Poisson arrival, general service, queuing system. The problem is to find a policy for controlling the service rate which minimizes the expected average service plus holding cost per unit time. We prove that under mild restrictions on the service and holding cost rates there exists a stationary deterministic optimal policy in which the service rate is a non decreasing function of the work remaining in the system. We also show that a particular continuous time decision problem is the limit of a sequence of discrete time problems.

FP7.16. A Mathematical Model of the Value of Achievement Test Information, PAUL D PINSKY.

This paper presents a mathematical model of the value of achievement test information in an instructional management environment. The student is considered to be in one of two states, either progressing at the proper pace (state c), or not progressing at the proper pace (state uc). Over time the students transfer from state c to state uc according to either a uniform or exponential failure rate. Once a student takes a test of length β, he transfers to state c with probability p (β). Both infinite and finite horizon models are considered. Under the assumptions of the various models presented, optimum (in terms of frequency and length) achievement testing procedures are found.

FP7.17. Operations Research and the Prison/Parole System—a Markov Example, PIERRE M. TULLIER.

The prison/parole system is a major part of the crimal justice system. Its main function is to protect the community from the criminal, while preparing the criminal for a useful life in the community. In many states when a man is released from prison he is given between $0 and $50. When the money runs out and he has no job, crime is a tempting solution. If this man commits a crime, and is caught, and goes to prison for the average three year term it will cost the community about $20,000. In three years this story may be repeated. In this paper a simple Markov model is developed as an example of Operations Research application in this important area. The states are—IN and OUT of prison. Data from the California system is used.

FP8.1. The Generalized Lattice Point Problem, FRED GLOVER and DARWIN KLINGMAN.

The generalized lattice point problem, posed by Charnes and studied by M. J. L. Kirby, H. Love and others, is a linear program whose solutions are constrained to be extreme points of a specified polytope. We show how to exploit this and more general problems (subsuming mixed integer programs) by convexity (or intersection) cut strategies without resorting to standard problem augmenting techniques such as in-

troducing 0–1 variables. In addition, we show how to circumvent massive "degeneracy" difficulties attending this problem without relying on perturbation (which provides uselessly shallow cuts) by identifying nondegenerate subregions relative to which cuts may be effectively defined.

FP8.2. Some Common Errors Associated with Regression Analysis, MURLE J. ATHERTON.

This paper considers a number of the most common and troublesome errors associated with the use of linear regression analysis. These errors include the interpretation of parameters such as the multiple correlation coefficient, the standard error of an estimate, and the *F*-value for goodness of fit. Also covered are errors related to confidence intervals, extrapolation, the use of residuals, collinearity, correlated response variables, and overfitting. Examples and circumventions, or at least references in which the circumventions are given, are included when possible.

FP8.3. Surveillance Aircraft Cost Model, MICHAEL B. BRYANT and PATRICK SMOCK.

This cost model is characterized by the basic premise that a selected airframe configuration to comply with a set of specific tactical mission requirements can be achieved by a single or mixed model, multi-mission surveillance aircraft company. The general "Linear Programming Optimization Problem" employing the "Simplex" solution method is used for the airframe configuration (i.e. allocation of mission oriented equipment). The "Assignment Problem Technique" is used for the solution of the life cycle provisioning problem of logistical and maintenance support. Venn diagrams are used to illustrate the relationships of each specific mission to the total mission capability.

FP8.4. Study of the Police Patrol Vehicle, HERBERT G. LUDWIG.

The goal of the research was to gain an understanding of the vehicle in relation to the police departments, and from this understanding, to aid the departments in procuring a better vehicle for police purposes, in developing a better set of policies for its use and in generating a better program for its operation and replacement.

The scope of the report includes the role of the vehicle, human factors, the design of a front seat console, specification recommendations and maintenance aspects

FP8.5. Computer Simulation of Initial Attack on Forest Fires, FREDERICK W. BRATTEN.

The initial attack simulation is a part of a larger simulation for evaluation of fire protection plans for a land management unit such as a National Forest. Three major problems were: (1) Mathematical descriptions of the initial attack system elements, (2) Explication of the force dispatching decision process, and (3) Calculation of the effectiveness of attack forces. Solutions to these problems and a sample problem with results are given.

FP8.6. *C*omputer-*O*ptimized *B*us *R*un-Cutting *A*lgorithm: The COBRA Model, EDWARD LIEBERMAN and R. J. JABBUR.

An algorithm which assigns bus operators to a transit system to satisfy a specified schedule so as to minimize total labor cost, has been developed. The algorithm reflects the simulation approach to the problem, whereby a heuristic decision policy is implemented at each relief point based upon present conditions and near-term consequences. A hierarchy of criteria representing both contractual regulations between the transit company and the union, together with constraints to minimize cost, forms the basis for the decision policy. The model has been programmed and the run-cutting procedure is completely automatic, requiring no manual intervention.

FP8.7. An Investigation of the Eye Movements of Pilots Engaged in Visual Search Under Actual Conditions, JOHN L. SMITH.

The corneal reflection technique was used to collect data on the eye movements of

experienced pilots engaged in an active visual search for airborne hazards. Actual data collection was accomplished in C-131 aircraft under a uniformly overcast sky that provided a background of relatively even luminance and reasonably free of distractions.

Fixations and total fixation time were distributed in a well-defined pattern showing marked differences in the degree of concentration within the field. A consistent shortening of the distance between fixations and an altering of the sequence of fixations was found as search neared the area of most intense concentration.

FP8.8. Integer Solutions to Convex or Concave Programming Problems, JOEL WEISMAN and KRISHNAN CHITKARA.

To obtain optimal all integer solutions, constraints are incorporated into an augmented objective function using an internal point penalty function technique. Each of n integer variables is expressed as a linear combination of 0–1 variables. Linear constraints allow only one variable per combination to be unity. The problem is then solved by a linearization procedure similar to "approximation programming". Since n linear constraints are set at unity, and each variable appears in one constraint, basic solutions are automatically integer solutions. Resolution at a successively higher penalty levels determines the optimal solution. The method is readily extended to mixed integer problems.

FP8.9. Geometric Programming and the Optimal Design of a Water Quality System, J. G. ECKER.

In this paper we present a geometric programming model for optimally maintaining certain minimum water quality standards throughout a river system. Waste treatment plants in various reaches consist of several processes acting in series with a nonlinear cost associated with the fraction of biological oxygen demand removed by an individual process. From the structure of the model it follows that the total cost of all alternative abatement methods can be expressed as a function of the stream quality in the various reaches which allows for an interesting interplay between geometric and dynamic programming.

FP8.10. The Linear Complementarity Problem in Complex Space, CHARLES J MC CALLUM, JR

Duality theorems for linear and quadratic programming have recently been extended to complex space by Levinson and by Hanson and Mond. In real space, linear and (convex) quadratic programs can be unified by the Linear Complementarity Problem (LCP) for which pivoting algorithms are available. In this paper, a similar result is sought for complex space. The Complex LCP is formulated and is shown to give complex linear and quadratic programs as special cases. An existance theory is developed and a solution procedure is given which involves a transformation of the problem and the use of real space pivoting theory.

FP8.11. Press Run Sequencing for Multi-Edition Periodicals, SHERIF M. NASR and JOSEF LUBENOW.

This paper deals with the problem of producing run sequences for presses printing multi-edition periodicals, in order to reduce printing costs, increase operating efficiency, and ultimately to allow for additional editions, thereby reaching previously unavailable advertising markets. The problem is analogous to minimizing the expense for a variable number of salesmen to visit a large number of towns. Each visit involves a cost composed of five variables and must fulfill two or more constraints The mathematical model for the system is presented, the heuristic solution as developed is discussed, and a comparison between computer results and the manually produced run sequences is given.

FP8.12. The General Truck Dispatching Problem, JACQUES H. DALLOZ.

This paper treats the optimum partitioning of a set A of demand points to be supplied from a center a_0. The Truck Dispatching Problem is generalized by introducing a

more general objective function and using the notion of "generalized saving" of a subset A_i with respect to the center. Given a cost function on the power set of A, it is desired to find a partition of the set A that leads to the minimum total cost of distribution to A from a_0, subject to the set of "physical" constraints of the system.

FP8.13. Labor Idle Time Versus Manufacturing, PAUL Z. CUMMINS, II.

During the execution of a production schedule, the manager may find that a situation will arise requiring the manufacture of a substitute product. A wrong decision could mean that unnecessary finished goods would remain in inventory an excessive period of time, actually reducing the margin to a loss. The analysis provides a method and decision table summary to clarify the decision considering significant factors as margin, inventory time, material usage and labor costs.

FP8.14. A Variant of Klein's Method For Minimal Cost Flows, G. E. BENNINGTON.

One of the methods for solving minimal cost flow problems is due to Klein and relies on finding cycles of negative length in a modified graph. These negative cycles correspond to a change in the flows around the cycle which will result in a reduction in the total cost. Although any method of determining negative cycles will suffice, the method normally suggested is to attempt to find the shortest chain between every pair of nodes. The method to be discussed will find the negative cycles by attempting to find the shortest chains from a *fixed* noded to all other nodes. Several algorithms for this method will be discussed.

FP8.15. Steady State Waiting Time in a Multi Center Job Shop, ASHA SETH KAPADIA.

This paper considers a job show with N machine centers. The number of machines at machine center i is taken to be m_j. Transitions by a job from one machine center to another are governed by a transition probability matrix. Assuming Poisson arrival of jobs into the job shop, exponential service at each machine center and a finite distance between two machine centers, the mean and variance of the time through the job shop are obtained under steady state conditions.

FP8.16. Optimal Issuing Policies for Perishable Inventory, WILLIAM P. PIERSKALLA and CHRIS D. ROACH.

Optimal issuing policies for some particular classes of perishable inventory problems are derived under several possible objective functions. The inventory considered is one in which stock is grouped into categories according to shelf age. Demand occurs for each of the categories and may be satisfied by inventory units from that category or from any "younger" category. It is shown for the objective functions considered, the optimal policy is to issue the oldest unit which will satisfy the demand. A prime example of the classes of inventory problems considered in this paper is the issuance of whole blood from a hospital or central blood bank.

FP8.17. Admission-Scheduling Model for Hospital, ISHWAR GUPTA and M. ZIA HASSAN.

This paper discusses an approach to build a mathematical model to determine admission policy by type of patient for effective allocation and utilization of hospital resources. This model recognizes admission-urgency of each prospective patient as well as the resources required by each patient. Resource requirements are computed for each patient from his present state of required care and his predicted future states. This approach would utilize hospital resources more effectively, by matching hospital resources to cumulative patient demand, would reduce patient's length of stay and thus would cut costs both for patient and hospital.

FP8.18. The Direct Approach to Approximate Decision Models, JOHN O. McCLAIN.

A decision maker who is burdened with a never-ending series of decisions may wish to delegate part of his task to a subordinate. His instructions to the subordinate

constitute a model for screening the cases; the decision maker thus reserves only the difficult or interesting cases for himself. This paper describes a method by which an investigator can derive a screening model with the aid of the decision maker. The method is applied to Medical Care Evaluation, in which the decision makers, doctors, are skeptical about "outside help". Methods of testing the results are also discussed.

FP8.19. Algorithms for Scheduling n Jobs in a Flowshop, JATINDER N. D. GUPTA and ALBERT R. MAYKUT.

The classical problem of scheduling n jobs on M machines in a flowshop to minimize the throughput time of all jobs is examined under the assumption that all jobs are processed on all machines in the same order. Based on the mathematical formulation of the job and machine slacks, a schedule evaluation algorithm is presented which consists of annotating the process time array. This proposed sequence evaluation algorithm identifies those jobs that are critical to the completion time of any job—thus yielding the critical path(s) and illustrates the manner in which job and machine slacks propagate through the flowshop. By defining and exploiting the concept of a synthetic job to represent a partial sequence, the basic ideas of the sequence evaluation algorithm are generalized to the point where they can serve as heuristic approaches to flowshop scheduling problem. One such algorithm, based on Gupta's idle time rule, is described and its performance (regarding its computational efficiency and solution effectiveness) discussed.

FP8.20. Appraising Feasibility and Maximal Flow Capacity of a Network, ALAN W. McMASTERS.

The use of the dual graph in determining the value of the maximal flow capacity of an undirected network has been extended to directed networks. A directed dual graph is defined such that the length of the shortest route through this dual is equal to the maximal flow capacity of its directed primal. Feasibility of networks having positive lower bounds on arc flows can also be appraised. Infeasibility is indicated by a cycle of negative length in the dual graph.

Society Affairs

MINUTES OF THE ORSA COUNCIL MEETING

27–28 October 1970

The Thirty-Eighth Meeting of the Council of the *Operations Research Society of America* convened at 7:30 P.M. on 27 October 1970 at the Statler Hilton, Detroit, Michigan, with W. Edward Cushen, President, presiding, and adjourned at 10:30 P.M. The Council reconvened on 28 October at 9:00 A.M., adjourning finally at 11:15 P.M. The following items are reported from the meeting. (Complete minutes are obtainable from the Secretary of ORSA.)

FUTURE ORSA MEETINGS

No.	Dates	Location	Chairman
39	5–7 May 1971	Dallas Sheraton Dallas	RONALD L GUE *The MEDICUS Corporation* *1104 Expressway Tower* *Dallas, Texas 75206*
40	27–29 Oct. 1971	Los Angeles Disneyland Hotel (joint with SSCG)	GERHARD L HOLLANDER *Hollander Associates* *P.O. Box 2276* *Fullerton, Calif. 92633*
41	26–28 April 1972	New Orleans Jung Hotel (joint with AIIE)	RICHARD E. BECKWITH *School of Business Admin.* *Tulane University* *New Orleans, Louisiana 70118*
42	8–10 Nov. 1972	Atlantic City Chalfonte-Haddon Hall (with AIIE, TIMS)	ROBERT M. STARK *University of Delaware* *Newark, Delaware 19711*
43	21–23 May 1973	Milwaukee Pfister Hotel	JAMES F. BANTON *Rex Chain Belt, Inc* *16455 West Bluemond Road* *Brookfield, Wisc. 53005*
44	12–14 Nov. 1973	San Diego	JOSEPH V. RAVENIS, II *Res. & Adv. Tech (7-17)* *Gen. Dynamics Electronics Div.* *3090 Pacific Highway* *San Diego, California 92112*

NO.	DATES	LOCATION	CHAIRMAN
(Continued)			
45	22–24 April 1974	Boston	
46	Fall 1974	San Juan	ARMANDO RIESCO *Dept of Industrial and Systems Engineering* *University of Puerto Rico* *Mayaguez, Puerto Rico*

IFORS: ORSA's Representative to the Program Planning Committee of the IFORS Conference in August 1972, at Trinity College, Dublin, reports a program of invited highlight and state-of-the-art papers, plus working groups and idea sessions. The Cost-Effectiveness Section of ORSA, host of the IFORS International Cost-Effectiveness Conference on 12-15 April 1971, at the Statler Hilton, Washington, D.C., is inviting 300 people from the United States and 100 people from other countries, including those from the Eastern bloc. Transfer of financial responsibility for IAOR from ORSA to IFORS is to be effective January 1971. IAOR will be offered to ORSA members as an optional increase in dues in 1972.

LANCHESTER PRIZE COMMITTEE: The Council approved the award of the 1969 Lanchester Prize to Harvey M. Wagner for his book, PRINCIPLES OF OPERATIONS RESEARCH, Prentice-Hall, Inc., 1969. Special mention was given to: M. G. Bekker, INTRODUCTION TO TERRAIN-VEHICLE SYSTEMS· J.C.D. Little and L.M. Lodish, A MEDIA PLANNING CALCULUS; and W.I. Zangwill, NONLINEAR PROGRAMMING· A UNIFIED APPROACH.

NOMINATIONS: The following slate has been announced by the Nominating Committee:

Vice President/President-elect:	LESLIE C EDIE WILLIAM J. HORVATH
Secretary	ROBERT M. OLIVER
Treasurer	DAVID M BOODMAN ROBERT G. BROWN
Council (two to be elected)	LOUIS P. CLARK WILLIAM R. KING GEORGE NEMHAUSER STEPHEN M. POLLOCK

AAAS: ORSA is principal organizer of three programs at the annual American Association for the Advancement of Science meeting in Chicago on 26–31 December 1970. Proceedings of the symposium sponsored by the Health Applications Section at the AAAS meeting will be published. With the American Astronomical and American Astronautical Societies, ORSA is planning a meeting on FUTURE SPACE ASTRONOMY PLATFORMS in December 1971 at Philadelphia.

CBMS: The Council authorized $1000 for annual membership in the Conference Board of the Mathematical Sciences.

AD HOC GUIDELINES COMMITTEE. By mail ballot, the Council will take appropriate action with respect to the Committee's final report, consisting of guidelines for professional practice, and including its conclusions and recommendations.

GEOGRAPHICAL/STUDENT SECTIONS· The formation of the University of Michigan Student Section was approved conditionally upon formal provision in its constitution for nominations of student officers by petition or from the floor

TECHNICAL SECTIONS· Budgets totalling $15,330 were approved for the Technical Sections. A limit of $250 for prizes was placed on each section. An advance of $2,000 for a Symposium on Pollution to be sponsored by the Urban Sciences Section in

Philadelphia in March of 1971 was authorized subject to approval of a written plan by the Technical Sections Committee Chairman and the ORSA Treasurer.

PORS: The Council authorized replenishment of the $6,000 reserve fund for the PORS Series, and noted that the Series was doing what it was set up to do.

PUBLICATIONS: The Council approved an increased budget maximum of $20,000 for OPERATIONS RESEARCH. The Council approved the creation of a quarterly news magazine of the Society with a budget of $10,000 per year. Armand B. Weiss will serve as editor.

EDUCATION COMMITTEE: The Council approved action by the Committee to renew its application for a continuing grant from NSF for the Program of Visiting Lecturers, beginning its fourth year. The Institute of Management Science is to be invited to participate with ORSA in the Program, subsequently to be called the Program of Visiting Lecturers in Operations Research and Management Science.

MEMBERSHIP: As of 30 September 1970, there were 2403 Members, 4756 associate members, and 890 student associate members, for a total membership of 8049.

NEW MEMBERS: The Membership Committee reported its nominees for full Membership. The following were elected by the Council as new Members.

Hebron E. Adams
Robert E. Alger
David E. Allen
William P. Allman
Kashi R. Balachandran
Dietrich R. Bergman
P. Bruce Berra
Haig E. Bohigian
Francesco Brioschi
Leonard M. Brush
Bruce Bundsen
Claude A. Burdet
John S Chipman
Daniel J. Couger
James C. Criner
John L. Davis
Reed E Davis, Jr.
Cree S. Dawson
Leopold Dor
John M. Dutton
Hamed K. Eldin
Sedat S. Ercan
Leonard Evans
John C. Even, Jr.
Steven A. Frank
James H. Gardner
James R. Gillespie
Phillip Gould
John Gratwick
David H. Gustafson
Paul W. Hammelman
David H. Harris
Virgil E. Henderson, Jr.
Kimio Ishimaru
Walter T. Jones
Yasutada Kashiwagi
Tenny N. Lam
Thomas A. Lambe
Albert S Lang
George P. Lewett
Edwin Levy
David V. Mastran
Edwin H. Neave
Arthur L. O'Toole
Denys D. Overhalser
Richard L. Patterson
Richard Y. Pei
Bruce A. Powell
Lewis G. Pringle
Reza Razani
John H. Reed
Allen F. Rehert
Tyrouza T. Richmond
Donald C. Riedel
R. T. Rozwadowski
Bernard H. Rudwick
Rajendra Saroop
James E. Shamblin
Jeremy F. Shapiro
N. D. Singpurwalla
Ronald W. Skeith
Dennis E. Smith
Alexis N. Sommers
Sibel Tanberk
Frank A. Tillman
Zev Ullman
Vernon E. Unger, Jr.
Allan Van Duren
Albert C. Vosburg
Vukan R. Vuchic
Paul P. Wang
Charles Karl Weber
Harry Williams, Jr.
Myron A. Wilson
Dennis R. Young
Steven M. Zimmerman
Thorvald K. Zimmerman

ROBERT M. OLIVER
Secretary

REPORT OF COMMITTEE ON LANCHESTER PRIZE FOR 1969

Many excellent papers and books published in 1969 were nominated for the Lanchester Prize of $2,000 that is awarded by the Operations Research Society of America. One of these, the book

Principles of Operations Research, Prentice-Hall, Inc., 1084 pages, by Harvey M. Wagner, is outstanding in several of the criteria on which judgment is made. This book is a

monumental effort that should contribute much to the use and understanding of operations research methods, now and in the future. The Committee on the Lanchester Prize for 1969 is pleased to award the prize to this book and congratulates Professor Wagner on a job very well done.

Although the prize selection was unanimous on the first ballot, some other nominations warrant special mention. These include *Introduction to Terrain-Vehicle Systems* by M. G. Bekker, a classic example of applied operations research, "A Media Planning Calculus" by John D. C. Little and Leonard M. Lodish, a realistic approach to an important set of problems, and *Nonlinear Programming: A Unified Approach* by Willard I. Zangwill, a research monograph in an important area.

JOHN E. WALSH *(Chairman)*
JOSEPH H. ENGEL
ALAN J. GOLDMAN
RONALD L. GUE *(Secretary)*

CORRECTIONS FOR DIRECTORY

A total of 36 names were inadvertenly left out of the 1970–1971 ORSA Directory. They are listed below.

HEEREMANS, James H. (M), Arthur Anderson & Co., 294 Washington St., Boston, Massachusetts 02108
HEFLEY, Gerald L. (SAM), P.O. Box 12171, Gainesville, Florida 32601 (U of Fla)
HEFLIN, Bill (M), GPD Mgmt Sys Branch, P.O. Box 6015, Mail Sta 229, Dallas, Texas 75222 (MAS, CES)
HEGERICH, R. L. (AM), 219 Columbia, Leavenworth, Kansas 66048
HEIDER, Frederick (AM), 20277 Westhaven La., Rocky River, Ohio 44116 (Ernst & Ernst)
HEIDORN, George Emil (AM), 1430 Augusta Pl., Monterey, California 93940 (US Naval Postgrad Sch)
HEIL, James H. (M), 9 Longview Ave., N. Caldwell, New Jersey 07006 (IBM) (MAS, SSS)
HEILBERG, Ernest (M), 5936 Thomas Dr., Springfield, Virginia 22150 (Tech Oper Inc) (MAS)
HEILBRON, Richard (AM), 501 Hillsboro Rd., Silver Spring, Maryland 20902
HEILENDAY, Frank W. (M), 617 South 37th St , Omaha, Nebraska 68105
HEILPRIN, Lawrence B. (M), 6402 Tone Dr., Bethesda, Maryland 20034
HEIM, William Robert (AM), Box 11 NSD, FPO US Forces, Seattle, Washington 98762 (USN) (MAS)
HEIMOWITZ, Carl L. (AM), 555 Mt. Prospect Ave., Irving Trust Co., Newark, New Jersey 07104
HEIN, Fernando X. (AM), Casilla de Correo 1811, La Paz, Bolivia
HEINRICH, AM (AM), P. O. Box 231, Campbell, California 95008 (TSS)
HEINSTAND, Peter J. (AM), H. P. Hood & Sons, 500 Rutherford Ave., Charleston, Massachusetts 02129
HEISKALA, Victor H. (AM), Litton Sci Support Lab, Fort Ord, California 93941 (MAS)
HEIT, Paul (M), c/o Lybrand Ross Bros & Montgomery, 60 Broad St., New York, New York 10004
HEITLER, Richard B. (AM), Merlin Systems Corp., 1044 Northern Blvd., Roslyn, New York 11576 (TSS, HAS)
HEITMAN, Richard E. (M), 117 Hosmer St., Action, Massachusetts 01720
HEIZER, David N (AM), 175 Morris Ave., Mt. Lakes, New Jersey 07046
HEKIMIAN, Kenneth K. (SAM), 514 Wilcox Ave #8, Montevello, California 90640 (U of So Calif) (CES)

HELAMERI, Kalle S. (AM), Huovitie 1 A 19, Helsinki 40, Finland
HELANDER, Robert E. (AM), 1431 Annajeanne Dr., Placentia, California 93670
HELD, Michael (M), IBM Sys Res Inst, 787 United Nations Plaza, New York, New York 10017
HELFAND, Richard M. (AM), 337 South Hampton St., Manassas, Virginia 22110 (Mitre Corp)
HELFRICH, Elton C. (M), 2480 San Carlos Circle, Colorado Springs, Colorado 80909 (MAS)
HELGASON, Thorkell (SAM), Westage Apt. 1210, Cambridge, Massachusetts 02139 (MIT)
HELLER, Nelson B. (AM), 399 North 4th St. 2730, St. Louis, Missouri 63102 (St. Louis Metro Police Dept)
HELLERMAN, Eli (AM), 720 Whitaker Terrace, Silver Spring, Maryland 20901 (CES)
HELLMAN, Louis P. (M), 1190 W. Northern Pkwy, Baltimore, Maryland 21210 (MD Reg. Medical Prog) (CES, HAS)
HELLY, Walter (M), 91 Central Park West, New York, New York 10023 (CES, TSS, ESS)
HELM, James Carlton (SAM), 904 Delma, Bryan, Texas 77801
HELMBOLD, Robert L. (AM), 18671 Ludlow St., Northridge, California 91325 (MAS)
HELMER, Olaf (M), Riverview Center Inst for the Future, Middletown, Connecticut 06457
HELMICK, Norman E. (AM), 848 S. Gramercy Dr., Los Angeles, California 90005

MEMORANDUM TO ORSA MEMBERSHIP FROM THE PRESIDENT-ELECT

I should like to solicit your help and advice in carrying out programs for the Operations Research Society of America. Because of the decentralized manner in which the Society operates, you can be most helpful and get most direct results if you correspond directly with the Chairman of the appropriate committee. I would be most pleased to receive carbon copies of any correspondence you address to them. With this in mind, I list below some of our committees, the name and address of the man whom I propose to appoint as Chairman of that Committee, some of the duties of that committee, and the kinds of ways in which you might help.

1. *Meetings Committee.* Chairman LEO ROGIN, Systems Analysis & Engineering Department, NADC, Warminster, Pennsylvania 18974.

The schedule of our future meetings is published elsewhere in this issue. If you would like to help at one of these meetings that is in or near your town, or if you would like to suggest that your town be a location for a future meeting, then Leo Rogin would be pleased to hear from you. Some of these meetings still do not have a General Chairman appointed. If the general Chairman is listed, you may wish to get in touch directly with him.

2. *Publications Committee.* Chairman. PAUL GRAY, Stanford Research Institute, 333 Ravenswood, Menlo Park, California 94025.

We are always anxious to have suggestions for improving our publications. The most usual suggestions in the past have been to make *Operations Research* more relevant and have more applications papers. I believe that the Journal has been much improved in recent years, but, in general, these types of suggestions are more difficult to implement than appears at first sight. Meanwhile, our present Publications Committee Chairman, Al Blumstein, is developing a new journal, to be called *OR/SA TODAY*, under the editorship of Armand Weiss. It will incorporate the material which is presently in the "Society Affairs" section of the *Bulletin*, act as a newsletter, and take as its models such journals as *Physics Today* and *Spectrum.* Any suggestions or offers of help or contributions will, I am sure, be gratefully received. In addition, the Publications Committee

is responsible for the books which we publish under the arrangement with Wiley. It has recently given up responsibility for International Abstracts in Operations Research, and any comments on this should be sent directly to its Editor, Hugh Bradley, The Upjohn Co., Kalamazoo, Michigan 49001.

3. *Nominating Committee.* Chairman: KENNETH YARNOLD, P.O. Box 2232, San Ysidro, California 92073.

This committee will be responsible for selecting two candidates for Vice President/President Elect and four candidates for Council. It will presumably nominate the incumbent secretary for his third and the incumbent treasurer for his second year without opposition, since these have traditionally been three-year jobs in our society. The Chairman would be pleased to hear any suggestions you may have. More of you would probably be interested in suggesting members for our committees. Such suggestion might, of course, include yourself. If you would like to serve this year, I suggest you contact the Chairman of the Committee. However, most of the Committee members have already been determined for this year. It might be more appropriate for you to contact the President Elect, whose name will be announced at the Dallas Meeting, about putting you on a committee for the following year.

4. *Education Committee.* Chairman: DAVID SCHRADY, Naval Postgraduate School, Monterey, California 93940.

The Committee would be interested in suggestions as to how it might function more effectively. At present, it collects and distributes information on the various programs available in Operations Research and also administers the visiting lectureship program. It should be noted that this committee is concerned with how to teach people to be operations analysts. The question of how to apply Operations Research to educational institutions is the responsibility of our Educational Sciences Section, Chairman, Professor Gustav Rath. Address. Dept. of Systems Engineering, University of Illinois at Chicago Circle, Chicago, Illinois.

5. *Lanchester Prize Committee.* Chairman: JOSEPH ENGEL.

This committee will award a prize of $2,000 and a plaque to the author of the best paper or book on Operations Research published in 1970. The Chairman would appreciate nominations.

6. *Geographical and Student Sections Committee.* Chairman: STEVEN POLLOCK, Dept. of Ind. Eng., 231 West Eng. Bldg., University of Michigan, Ann Arbor, Michigan 48104.

7. *Technical Sections Committee.* Chairman: BURTON DEAN, Dept of Oper. Res., Case Western Reserve University, University Circle, Cleveland, Ohio 44106.

The old "Sections Committee" is now these two committees, and may soon be three. If you would like to start a section, or help in the work of a section, or find out what section you can join, please communicate with the Chairman.

8. *Amendments Committee.* Chairman. JACK BORSTING, Dept. of Oper. Anal., U.S. Naval Postgrad School. Monterey, California 93940.

A change in Article VIII of our constitution appears in order because of a technicality. While we are at it, it seems desirable to review the entire Constitution and

By-laws for other possible changes. For example, the references to "25 members" in Articles VIII, X, and XI were inserted at a time when our membership was about 200. At the present time, it is about 8,000. We might also like to re-examine our classes of membership, our committee structure, and the like. Have you any suggestions for changes?

9. *Membership Committee.* Chairman JOHN HONIG, 7701 Glenmore Spring Way, Bethesda, Maryland 20034.

This committee is charged with the thankless task of deciding which of our associate members should be Members. Only one-third of our members are Members (small m means they pay dues and receive journals, large M means they can vote and hold office). If you wish to nominate yourself or anyone else for upgrading, write to John Honig, or to our Business Manager, Norvell Miller III, address: 428 East Preston Street, Baltimore, Maryland 21202.

10. *Committee as yet unnamed.* Chairman: DAVID KATCHER, Arthur D. Little, Inc., 35 Acorn Park, Cambridge, Massachusetts 02140.

This committee will think about various things the Secretary ought to be doing. In particular, I have asked it to take such actions as may be appropriate to increase our membership by solicitation among OR professionals who are not now members of ORSA.

11. *Liaison.*

We now have a plan to have liaison representatives with National Research Council (Hugh Miser), the American Association for the Advancement of Science (Walter Deemer and George Morgenthaler), the Conference Board on Mathematical Sciences (Donald Igelhart and Jack Borsting) the Society of Actuaries (Gorden Shellard), and the Systems Science and Cybernetics Group of the IEEE (Ronald Howard). If you have any suggestions for our interaction with these organizations, please contact the appropriate representative. If you think we should establish more formal liaison with other organizations, I would be pleased to hear about it.

Any suggestions you might wish to make, along any of these lines, will be much more helpful if they are well documented. For example, if you wish to suggest a man (including yourself) for any position, please enclose a vita and, within the limits of modesty, reasons why you think this would be a good man for the job you are suggesting If you wish to suggest any changes to the Constitution or By-laws, a detailed set of justifications and even a precise suggested wording would be helpful.

ORSA is one of the most effective professional societies that I know of, and one of the most democratic. To continue and increase these desirable characteristics, we need your help, your cooperation, and above all, your interest.

ROBERT E. MACHOL
Graduate School of Management
Northwestern University
339 East Chicago Avenue
Chicago, Illinois 60611

News and Announcements

OR/SA TODAY TO BE PUBLISHED BY SOCIETY

A new publication, to be entitled *OR/SA TODAY*, will be published by the Society starting in 1971. The publication is to be a newsletter issued quarterly and mailed to the membership. It will contain data on society affairs, news, announcements, and short articles of general interest to members It is intended to provide a more rapid means of disseminating information to members and to provide a forum for practitioners.

The Editor of *OR/SA TODAY* will be ARMAND B. WEISS, Logistics Management Institute, 4701 Sangamore Rd., Washington, D.C., 20016. Armand has long been active in Society affairs and was particularly instrumental in the continuing success of the Cost-Effectiveness Newsletter. He intends to follow a format similar to the Section newsletters, which has proved to be both easy to read and economical to produce. Members are urged to submit material for inclusion in *OR/SA* directly to Armand.

With the establishment of *OR/SA TODAY*, the Society Affairs and News and Announcement Sections of the Bulletin will be discontinued and the Bulletin will become only a meeting program.

40TH NATIONAL MEETING

The 1971 Fall meeting will be held on October 27–29, 1971 at the Disneyland Hotel in Anaheim, California. The meeting will be held as an adjunct meeting with the 1971 National Conference of the IEEE Systems, Man and Cybernetics Group as the Joint National Conference on Major Systems scheduled for the entire week, October 25–29, 1971. This conference will focus on social problems, environmental problems, and problems related to the ethical use of technology, as well as on other major systems problems of the 70's. Sessions are being organized in the following areas.

I. The Environmental Crisis
   1. Ethical use of Technology
   2. Urban Problems
   3. Ecological Management
   4. The use of Herbicides–
      A Case History

II. Problems of Major Systems
   1. Crime and Police Activities
   2. Justice and the Courts
   3. The Post Office
   4. Management of Operations
      Research

III. New Horizons in Systems Science

IV. ORSA Section Sessions

1. Cost Effectiveness
2. Military Applications
3. Transportation Sciences
4. Educational Sciences
5. Health Applications
6. Urban Affairs
7. Special Student Session

V. Contributed Papers Sessions

Certain innovative features will characterize this meeting. These include a paper fair featuring advances in methodology, a daily newsletter for attendees, a management information system designed to increase communication between attendees with common interests, and a series of activities (both formal and informal) that will explore the present employment situation and evolutionary direction of the future job market for professional analysts.

Submission of contributed papers on subjects of interest to the membership of the Society is encouraged. It is understood that such papers have not previously been published or presented at other meetings. Abstracts and titles of papers must be received by May 1, 1971 to be considered. Each abstract should (1) consist of a single paragraph not exceeding 100 words with no footnotes; (2) contain a heading including title of paper, author's name, professional affiliation, and business address; and (3) be typewritten, double spaced, and submitted in duplicate. Mail your abstracts to:

Dr. JOHN P. MAYBERRY
ORSA Program Committee
Lambda Corporation
1501 Wilson Blvd.
Rosslyn, Virginia 22209
(U.S. east of the
Mississippi and Eastern
Canada)

MR. MILTON KAMINS
ORSA Program Committee
RAND Corporation
1700 Main Street
Santa Monica, California 90406
(U.S. west of Mississippi and
all other foreign)

The program is still pliable and suggestions regarding its content are welcome. These should be directed to either the Program Chairman: Mr. Sidney Moglewer, McDonnell Douglas Corporation, Station 35-95, 3855 Lakewood Blvd., Long Beach, California 90801 or to ORSA Vice-Chairman: Dr. David Debeau, TRW Systems Group, E1/3013, One Space Park, Redondo Beach, California 90278. The General Chairman for the Joint National Conference on Major Systems is Mr. Gerhard Hollander, Hollander Associates, P.O. Box 2276, Fullerton, California 92633.

41ST NATIONAL MEETING

The 41st National Meeting of the Operations Research Society will be held April 26–28, 1972 in New Orleans at the Jung Hotel. This will be a joint meeting with the

American Institute of Industrial Engineers. Meeting Chairman is Richard E. Beckwith, Graduate School of Business Administration, Tulane University, New Orleans, Louisiana 70118.

SIXTH IFORS CONFERENCE, DUBLIN, 1972

The Sixth International Conference on Operational Research, sponsored by IFORS, will be held at Trinity College in Dublin, Ireland, from August 12–25, 1972. A major objective of this conference will be to demonstrate the capability of operations research to make a significant contribution to the solution of current problems at the national and international level as well as at the level of the firm or local authority. It will also aim at creating an environment designed to promote greater informal discussions between conference participants on topics of current interest. To this end, the conference will be structured at five distinct levels.

1. *Highlights:* After the opening session, three invited prominent speakers will address the conference on challenging problems of international and national concern to which OR can be usefully applied.

2. *State-of-the-Art:* Eight papers will be given by invited speakers, surveying the state-of-the-art in the several fields of operations research.

3. *National Contributions:* Each member society of IFORS is invited to select one one or more persons from its country (see details below) to present a paper.

4. *Workshop Sessions:* Problems of current interest not yet adequately structured will be considered in six to eight workshop sessions. The topics envisaged are the applications of OR in: educational systems, urban planning, guiding technological development, supranational problems, agricultural research, health and welfare systems, crime prevention and control, environmental pollution abatement.

5. *Discussion Forum:* Throughout the conference, facilities will be provided so that participants will have the opportunity, either in advance or during the course of the conference itself to initiate small informal groups to discuss any topic they may care to promote. These informal groups may be set up either by simply stating the subject of discussion or by contributing a paper to be made available for collection by interested participants at the start of the conference. Where advance notice has been given of an intention to hold a discussion group, the timetable for these groups will be published and made available to conference participants on arrival. Ad hoc discussion groups will be scheduled from day to day, and timetable agenda will be published daily.

The National Contributions

The member societies of IFORS are invited to select papers for the "National Contributions" sessions. The basis on which these papers should be selected is as follows.

(a) The paper should preferably not have been previously published. (But papers that have only been published in a journal with local circulation may be chosen.)

(b) It should refer to recent work.

(c) Papers reporting on specific application and well-balanced between theory and practice are preferred. But theoretical papers and review papers are acceptable subject to the condition that they should cover strategically related projects or related techniques. Blanket review papers reporting on the overall developments of operational research within a particular country are not encouraged.

Each member society has been invited to submit only one paper except for those countries with large OR societies who may submit the following numbers of papers: France (2), Germany (2), India (2), Japan (2), UK (3), and USA (3). The time allowed for the presentation of these papers will be 30 minutes, followed by 15 minutes for discussion.

The above conference plan requires that each member OR society select one or more speakers to present its National Contribution paper(s). George W. Morgenthaler, the U.S. delegate to the Program Committee is preparing a recommendation in this regard for the ORSA Council.

The number of conference attendees permitted an IFORS member society is also limited. It is a function of both the overall size of the conference and the relative size of the member OR society. Responsibility for selection and invitation of U.S. delegates rests with the ORSA representative to IFORS, Joseph Engel, operating under the general policies and direction of the ORSA Council. As a general rule, an effort is made to achieve a balanced delegation with respect to theoreticians versus practitioners; university, industry, and government members; geographical representation, etc. Since the potential contribution of a delegate to the conference will be taken into consideration in selecting the delegation, anyone interested in attending as a delegate should write to Joseph Engel or to George W. Morgenthaler, stating his interest, affiliation, and whether he would expect to participate in one of the eight Workshop sessions or in the Discussion Forum. A brief abstract of any possible contribution to the Discussion Forum would also be helpful. Delegates are expected to arrange for their own financial support in attending the conference.

IFORS INTERNATIONAL COST-EFFECTIVENESS CONFERENCE

The International Federation of Operations Research Societies is sponsoring an international conference on Cost-Effectiveness to be held in Washington, D.C., April 12–15, 1971. The meeting will be hosted by the Cost-Effectiveness Section of ORSA. The conference will include reviews of current cost-effectiveness analysis in the U.S. and several foreign countries; workshops in methodology and tools, applications, and case studies; and sessions on operation of cost-effectiveness analysis to management. W. Edward Cushen, President of ORSA, is general conference chairman.

TIMS MEETINGS

The XVIII International Meeting of TIMS will be held March 21–24, 1971, in Washington, D.C. at the Statler Hilton. The theme of this meeting will be International Horizons of Management Science.

The 12th American meeting is scheduled for September 29 through October 2 in Detroit in the Statler Hilton in that city. The Chairman of that meeting is F. M. Webster. Abstracts are due by April 15.

CORS MEETINGS

The 13th Annual Conference of the Canadian Operational Research Society will take place in Ottawa, Canada, 9, 10, 11 June, 1971. The theme of the Conference will be "Operational Research in the Public Sector."

Individual sessions will be devoted to OR theories and applications relating to all three levels of government—federal, provincial and municipal. Additional information may be obtained from. R. E. Boston, T. O. Box 973, Station "B", Ottawa, Ontario, Canada.

CORS, together with the Association Francaise pour la Cybernetique Economique et Technique (AFCET), will sponsor a conference on OR in banking and finance in

Montreal in the fall of this year. Details may be obtained from C. M. Papion, The Royal Bank of Canada, Box 6001, Montreal 101, P.Q., Canada.

NATO OPTIMIZATION CONFERENCE

A Conference on Applications of Optimization Methods for Large-Scale Resource-Allocation Problems will be held in Elsinore, Denmark, July 5–9, 1971. The Conference is sponsored by the NATO Science Committee and is under the Scientific Directorship of George B. Dantzig and Richard W. Cottle of Stanford University. Attendance will be limited to 120 persons.

The purpose of the Conference is to review and to advance the art of optimizing large-scale resource-allocation problems. Topics of interest include methodology for solving structured mathematical programs, models for national planning, experience with solving large-scale systems, and the need for experimentation.

Inquiries regarding the Conference may be addressed to Murray A. Geisler, The RAND Corporation, 1700 Main Street, Santa Monica, California 90406. He serves as the American point of contact.

OTHER NATO OR MEETINGS FOR 1971

In addition to the optimization meeting, NATO is sponsoring two other OR meetings in 1971:

"Manpower Planning Models", D. J. Clough, Director, United Kingdom, September 5–10, 1971.

"Operational Research in the Design of Electronic Data-Processing Systems", F Hanssmann, Director. Germany, September 13–17, 1971.

For additional information, write Scientific Affairs Division (Operational Research), NATO, 1110 Brussels, Belgium.

JOHNS HOPKINS LECTURES IN OR

George B. Dantzig, Professor of Operations Research and Computer Science at Stanford University will deliver a series of lectures on Mathematical programming at Johns Hopkins University on April 12 through 15. This will be the first of what are expected to be a continuing series of Johns Hopkins Press Lectures in Operations Research to be presented by distinguished scholars in the field. The lectures will be open to the public and will be published as a mongraph by the Johns Hopkins Press.

GORDON RESEARCH CONFERENCE OPERATIONS RESEARCH AND MANAGEMENT SCIENCE

On August 9–13, 1971, at Holderness, New Hampshire, the second Gordon Research Conference on Operations Research and Management Science will be held. The program being offered includes mathematical and behavioral approaches to decision theory, long-range planning, and nonlinear programming. The speakers will include: H. O. Hartley, Ward Edwards, Milt Godfrey, Russell W. Peterson, R. O. Mason, R. C. Meier, T. J. Gordon, and George D. Awkins.

The conferences were established to stimulate research in universities, research foundations and industry. This purpose is achieved by informal meetings mornings and evenings, Monday through Friday noon. The afternoons are available for recreation reading or participation in discussion groups, as the individual desires. The purpose of the program is to bring experts up to date on the latest developments, to analyze the significance of these developments and to provoke suggestions concerning the underlying theories and profitable methods of approach.

Attendance—limited to approximately 100 conferees—is by application on the standard form which may be obtained by writing Alexander M. Cruickshank, Department of Chemistry, University of Rhode Island, Kingston, Rhode Island 02881.

JOINT MEETING OF OPERATIONS RESEARCHERS IN THE FEDERAL GOVERNMENT AND THE PRIVATE RESEARCH SECTOR

The fourth joint meeting of Operations Researchers in the Federal Government and the Private Research Sector will be held at Gaithersburg, Maryland, May 24–26, 1971. The meeting will focus on "Critical Evaluation of Case Studies in Operations Research Prepared by Federal Agencies". The meeting is sponsored by the National Bureau of Standards and co-sponsored by 7 societies, including ORSA. For additional information, contact Roy Herrmann, Department of Management Science, The George Washington University, Washington, D.C. 20006.

REPORT ON OR ACTIVITIES IN CZECHOSLOVAKIA

(The following report was prepared by Michael Radnor and Robert E. Machol, both of the Graduate School of Management, Northwestern University. Support for U.S. Participants to attend this meeting was obtained from the National Science Foundation, Engineering Division).

In the 13 years since IFORS was founded 19 new national OR Societies, from almost every corner of the world, have joined the 3 original founders. Prominent by their absence have been the countries of Eastern Europe. However, while they have so far not been formally represented in the international OR community, this does not imply an absence of OR activities in these countries. To the contrary, several of them have considerable OR achievement to their credit of both theoretical and applied dimensions; and some, recently, have shown significant interest in forming OR societies and joining IFORS.

It was against this background that we recently took the opportunity to participate in an IFORS-sponsored international seminar on Algorithms for Production Control and Production Scheduling at Karlovy Vary (Carlsbad), Czechoslovakia, September 8 to 10, 1970. The conference, which was attended by some 300 participants from eight countries, was arranged by a committee representing various key contributing organizations. Among the Czechoslovak organizers and active participants were: M. Knotek—Conference Chairman (Deputy Director, Institute for Automation of Industrial Management (INORGA)—B. Mazel, Director); J. Habr—Deputy Conference Chairman (Head of Department of Economics Institute, Czechoslovak Academy of Sciences); J. Brynda (Deputy Director, Center for Automation); J. Walter (Professor and Head of OR Department, Prague School of Economics); M. Balda (Professor and Head of Automation Department, Technical University, Prague), and A. Klas (Director, Computer Research Center, United Nations Program for Central Europe in Bratislava).

The Conference was the second to be held in Czechoslovakia on Production Control Models—an area in which they have apparently elected to specialize. The six conference sessions were devoted to papers on Methodology, Production Scheduling and Control of

Cyclic Production, Flow Shop and Assembly Line Processes, and Production and Information Systems (Computer Control). Simultaneous translation of all papers into Russian, Czech, and English was provided. A Proceedings is to be published Mention was made of a follow-up conference on Production Models to be held at a future date in Czechoslovakia.

In our estimation the conference was a success and an important step in development of the emerging Czechoslovak OR Society. The impressive quantity and quality of their participation indicates that OR is thriving in the country, with a strong practical realistic emphasis to the work. In addition to their own efforts, they were able to attract a strong foreign delegation consisting of some 40 participants from Austria, France, Holland, the United Kingdom, the United States of America, the U.S.S.R., and West Germany. Amongst these were. R. Chapman (British Steel Corporation), S. L. Cook (Professor of OR, University of Aston), S. Eilon (Professor and Head of Department of Management Engineering, Imperial College of Science and Technology) in the United Kingdom delegation, W. Crowston (Professor, Massachusetts Institute of Technology), R. Dudek (Professor, University of Texas), R. Machol (Professor of Systems, Northwestern University), and M. Radnor (Professor and Chairman, Organization Behavior Department, Northwestern University) in the U.S.A. group; and a U.S S.R. delegation which included A. A. Belostotsky (Head, Production Control Department, Central Automation Institute, Moscow), G. I. Obraztsov (Director of the Ministry of Automation, Moscow and Head of the Delegation), Academician B. B. Timofeev (Professor and Director of the Automation Institute, Kiev), W. Valdenberg (Professor and Deputy Director of the Central Automation Institute, Moscow).

Greetings to the Conference from IFORS were presented by R. Machol, representing IFORS President Alec Lee, in which he expressed the hope that we would soon see the Czechoslovak Society in IFORS. In this regard an extremely significant event took place at the conclusion of the Seminar in a meeting between the conference organizers, the members of the United Kingdom, U.S.A., and U.S.S.R. delegations, and the President of the Czechoslovak Academy of Sciences, Jaroslov Kozenik. At that meeting President Kozenik agreed to give his critical support to the proposal that the Czechoslovak Society apply for IFORS membership. There were also indications at the meeting that a similar development was in the making in the U.S.S.R.

In summary we feel that the level of OR activity in Eastern Europe warrants closer contacts than have been evident in the past. There appears to be a genuine effort to maintain scientific links from the East, and we might hope for an increase in mutually beneficial contacts and joint programs in the future. Along these lines we might note the plans for some Czechoslovakian participation in the forthcoming IFORS Cost Effectiveness Conference in Washington, D.C., this spring, and also the decision by groups of both the Soviet Union and Czechoslovakia to participate in the Cooperative International Program of Research on Operations Research and the Management Sciences, a twenty-nation study coordinated through Northwestern University (M. Radnor, Program Co-ordinator).

Finally we must express our appreciation to the conference organizers for the excellent and warm hospitality provided to the foreign participants. Few of us will soon forget the final reception when an environment of good food, wine, and song in the best Central European tradition created a glimpse of "mutual understanding."

NEW JOURNAL ON MATHEMATICAL PROGRAMMING

A new bi-monthly journal, *Mathematical Programming,* will begin publishing in 1971. The Journal will be under the editorship of M. L. Balinski of the City University of New York. It will publish papers on theoretical, computational, and application aspects of mathematical programming. This includes, according to the prospectus, computer experimentation, techniques for formulating and applying mathematical programming

models, computer programming devices of special interest, unconstrained optimization, and control theory done in the spirit of mathematical programming, as well as the conventional topics in linear, non-linear, and integer programming. Subscriptions for 1971 are $40. Free sample copies may be obtained from North-Holland Publishing Company, Journal Division, P.O. Box 211, Amsterdam, The Netherlands.

LOW COST *CBMS NEWSLETTER* SUBSCRIPTIONS FOR ORSA MEMBERS

The Conference Board of the Mathematical Sciences announces that subscriptions to its *NEWSLETTER*, beginning with the January 1971 issue, are available at $2 (rather than $4) to individuals belonging to its member societies, including ORSA. The *NEWSLETTER* seeks to present up-to-date news and information of direct interest and relevance to the broad mathematical community represented by its member societies, including current programs and plans of agencies of the Federal government and private foundations affecting the mathematical sciences. Subscriptions may be addressed to CMBS, 2100 Pennsylvania Avenue, NW, # 834, Washington, D.C. 20037. Orders must be prepaid and should indicate your membership in ORSA.

AGIFORS SYMPOSIA PROCEEDINGS AVAILABLE

Proceedings of the 1969 AGIFORS (Airline Group of the International Federation of Operational Research Societies) Symposium are now available for $30 ($20 for airline personnel). Copies may be obtained from J. F. Wells, Jr., American Airlines, 360 Lexington Avenue, New York, New York 10017. These symposia have been held annually since 1961. Proceedings of all previous symposia, except 1965, are also available.

EDUCATION NEWS

The Education Committee will regularly publish information concerning degree programs in Operation Research. News of new programs or significant changes in existing programs should be sent to Professor D. Schrady, Chairman, ORSA Education Committee, Naval Postgraduate School, Monterey, California 93940.

University of North Carolina
Chapel Hill, North Carolina 27514

COURSE OFFERINGS

Primary Operations Research:

Deterministic Models of Operations Research
Stochastic Models of Operations Research
Linear Programming
Non-Linear Programming
Dynamic Programming
Queueing Theory
Network Flows and Scheduling
Inventory Theory
Simulation Theory
Optimization in Large Scale Systems
Advanced Topics in Management Science
Seminar: Recent Advances in Operations Research
Group Choice Behavior (game theory)

Information Systems for Statistical Problems
Data Representation and Manipulation
Data Processing and File Management
Mathematical Analysis
Mathematical Statistics
Introduction to Stochastic Processes
Advanced Microeconomic Theory
Systems Analysis

Associated with Operations Research

There are numerous courses involving operation research methodology or applications at the graduate level in the Departments of City and Regional Planning, Computer and Information Science, Economics, Psychology, Mathematics, Statistics, and the Graduate School of Business.

AREAS OF RECENT RESEARCH

nonlinear programming (theory and applications)
decision theory
large scale stochastic systems
pattern recognition
automata theory
queueing theory
combinatorial optimization

FULL-TIME ENROLLMENT (1970/71)

M.S. 8 Ph.D 7

The Curriculum in Operations Research and Systems Analysis is an applied area of mathematical science with wide ranging interests that cut across established disciplines. Both M.S. and Ph.D. degrees are offered. The unifying theme is a strong background in mathematics, statistics, and computer science, upon which a quantitative approach to model building and optimality analysis is developed. Based on this common background students may either pursue theoretic studies or follow an applied program geared toward applications in such areas as management science, urban studies, population studies, health science, public planning, transportation, and education. Inquiries should be sent to F. J. Gould, Chairman, Curriculum in Operations Research and Systems Analysis, 315 Phillips Hall, University of North Carolina, Chapel Hill, North Carolina 27514.

FACULTY

Primary Operations Research: T. Crabill, J. P. Evans, F. J. Gould, M. R. Leadbetter, J. L. Murphy, G. E. Nicholson, Jr., R. Shachtman, W. L. Smith, D. Stanat, J. Tolle, V. Wallace.

SUMMER SHORT COURSE OFFERINGS 1971

Each year, various Universities around the country offer short courses in both elementary and advanced aspects of Operations Research and related areas. The following list includes those schools whose offerings have come to the attention of the Editor.

University Extension
The University of Wisconsin
432 N. Lake Street
Madison, Wisconsin

Director,
Department of Continuing Education
Georgia Institute of Technology
Atlanta, Georgia 30332

Director of Continuing Education
College of Engineering
251 Carpenter Hall
Cornell University
Ithaca, New York 14850

Engineering Summer Conferences
The University of Michigan
Chrysler Center
Ann Arbor, Michigan 48105

Center for Advanced Engineering Study
Massachusetts Institute of Technology
Cambridge, Massachusetts 02139

Office of Continuing Studies
P.O. Box 1892
Rice University
Houston, Texas 77001

Program Promotion
Post Office Box 24902
University Extension, UCLA
Los Angeles, California 90024

ORSA members should contact these schools directly for information on offerings, dates, and fees.

PERSONALS

JAMES K. BYERS and JOHN B. PRATER have joined the faculty of the Department of Computer Science at the University of Missouri-Rolla and will work in the operations research area.

WALTER L. DEEMER, winner of the Lanchester Prize in 1957 and currently member of the Committee for Liaison with AAAS, retired after 29 years of government service on July 31, 1970. At the time of his retirement he was Deputy Assistant Director of the Arms Control and Disarmament Agency.

LEON B. ELLWEIN has been appointed Systems Analysis and Planning Officer for the National Cancer Institute, Bethesda, Maryland.

JOSEPH H. ENGEL, past President of the Operations Research Society and currently IFORS representative, has assumed the Chairmanship of the Advisory Panel on Operational Research of NATO.

BENJAMIN EPSTEIN has been appointed professor in the faculty of Industrial and Management Engineering at the Technion-Israel Institute of Technology, Haifa, Israel.

PETER G. FIELDING has been elected to Fellowship of the Royal Aeronautical Society.

F. T. HSU has been appointed Assistant Professor of Industrial Engineering and Operations Research at Wayne State University. He recently completed the first PhD in industrial engineering awarded by Kansas State University.

ROBERT W. JAILER has been promoted to principal of Planning Research Corporation.

TURKAN E. KUMBARACI has joined the research staff of the Applied Mathematics Department of Brookhaven National Laboratory, Upton, New York. Miss Kumbaraci was formerly Chairman of the Industrial Engineering Department, Middle East Technical University, Ankara, Turkey and had set up the department in 1968.

MICHAEL LEYZOREK has joined Cresap, McCormick and Paget, Inc. as Director of Management Sciences Services and has been elected a principal of the firm.

RICHARD W. LONGMIRE is now Associate Administrator for Planning, Research and Training of the Social and Rehabilitation Service of the U.S. Department of Health, Education, and Welfare.

DAVID M. MOSS has joined the Food and Drug Administration as Chief, Planning and Analysis Group, Office of the Assistant Director for Planning and Analysis, Bureau of Drugs.

DAVID S. STOLLER, member of the Council of the Society, has been appointed to the faculty of California State College, Fullerton, as Professor of Business Administration.

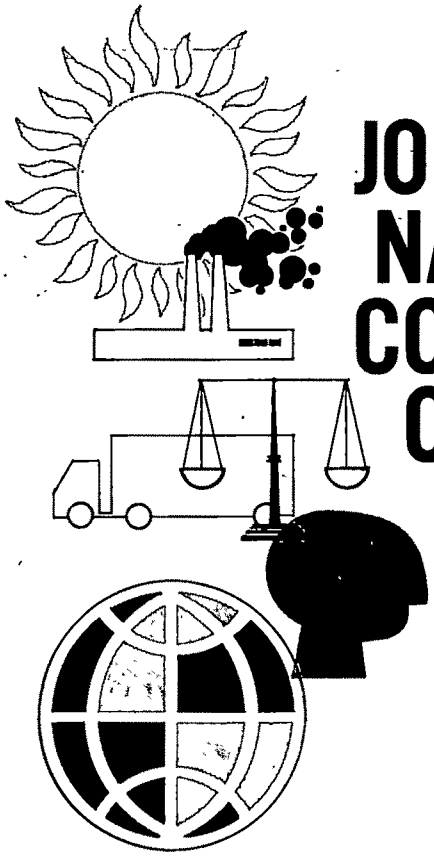
PAUL NAOR, Professor of the Faculty of Industrial and Management Engineering at the Technion, Haifa, Israel, died in an air accident over Romania on December 7, 1970. Professor Naor had long been active in operations research and had represented his country in IFORS. The following is the text of a letter sent to the Technion by J. H. Engel, U. S. Representative to IFORS.

News of the untimely death of Paul Naor has just reached me via an IFORS Newsletter. On behalf of Professor Naor's many friends in the Operations Research Society of America, I send our most sincere condolences and request that you express our deepest sympathy to his family.

I am personally saddened by this loss as I had known and worked with Professor Naor for many years. I believe our first meeting was at the First International Conference on Operational Research held in 1957 at Oxford, England. Subsequently, we met and corresponded on many occasions. I particularly enjoyed working with him when he and I were presidents of our respective O/R societies in planning the joint ORSIS/ORSA meeting held in Tel Aviv in the summer of 1969. That symposium was a great success and strengthened the ties of our two societies as well as many personal ties.

As a result of my acquaintance with Professor Naor, I came to have the highest regard for him—both as a warm-hearted colleague and friend. We will all miss him.

OCTOBER 25-29, 1971
DISNEYLAND HOTEL
ANAHEIM, CALIFORNIA



JOINT NATIONAL CONFERENCE ON MAJOR SYSTEMS

40TH NATIONAL
ORSA MEETING
OCTOBER 27-29, 1971

IEEE
SYSTEMS, MAN AND
CYBERNETICS GROUP
OCTOBER 25-27, 1971

OPERATIONS RESEARCH VOLUME 19 SUPPLEMENT 2 FALL 1971

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Operations Research Society of America
1971–1972

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BULLETIN

OF THE

Operations Research Society of America

Supplement 2 OPERATIONS RESEARCH Volume 19, 1971

Program of the Fortieth Meeting and the Joint National Conference on Major Systems

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JOINT NATIONAL CONFERENCE ON MAJOR SYSTEMS

STEERING COMMITTEE

General Chairman– GERHARD L. HOLLANDER, Hollander Associates, P.O. Box 2276, Fullerton, CA 92633

Secretary– BEN C. EDMONDSON, California State College, 800 N. State College Blvd., Fullerton, CA 92631

ORSA Vice Chairman– DAVID E. DEBEAU, 2012 Ruhland Ave., Redondo Beach, CA 90278

ORSA Program– SIDNEY MOGLEWER (McDonnell Douglas Corporation)

ORSA Treasurer– BYRON MARSHALL (Peat, Marwick, Mitchell & Co.)

IEEE Vice Chairman– DAVID H. WEIR, Systems Technology, Inc., 13766 Hawthorne Blvd., Hawthorne, CA 90250

IEEE Program– JOSE E. OLIVARES, JR. (Sysdyne, Inc.)

IEEE Treasurer– DON E. COLLINS (Autonetics)

Publications– EDMUND L. JUCEVIC (TRW)

Papers– FRANK J. MULLIN (TRW)

Joint Activities Vice Chairman– DALE O. COOPER, Getty Oil Company, P.O. Box 54050, Los Angeles, CA 90054

Activity Control– PERRI STINSON (California State College, Long Beach)

Advertising– LLOYD SEESE (Arthur Andersen & Co.)

Exhibits– PHILIPPE E. J. COTÉ (Alpha Beta Acme Markets, Inc.)

Hotel Arrangements – EUGENE E. PENTECOST (North American Rockwell)

Information Systems– JAMES E. TURNEY, JR. (Technicolor, Inc.)

Local Hosts– DAVID NEWBRO (North American Rockwell)

Program Innovations– ROBERT PERRY (Consultant)

Publicity– JAMES F. HIGGIN (Litton Industries)

Registration– WALTER H. KROY, McDonnell Douglas Astronautics Company, A-830-BBEO, Mail Station 17, 5301 Bolsa Ave., Huntington Beach, CA 92647

Foreign Activities– ALLEN STUBBERUD (University of California, Irvine)

ORSA PROGRAM COMMITTEE

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STANLEY DOLINS (Department of Defense)

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GENERAL CHAIRMAN'S STATEMENT

Objective: Relevant Communication

This conference combines the national meetings of ORSA and the IEEE Systems, Man & Cybernetics Group. Monday and Tuesday have been arranged by IEEE; Thursday and Friday, by ORSA. The papers demonstrate that systems engineers and operations researchers share the same problems and seek the same solutions. The similarities in the theoretical structures allow a technology transfer from one application to another.

This meeting has been planned to achieve two primary objectives: total communication and relevancy to today's needs. Unconventional activities are designed to further these two objectives.

For relevancy, the program focuses on the real applications of operations research. Plenary sessions are organized around applications to ensure a continual dialogue between the technique developers and users.

Total communication is more than passive listening. Critical discussion and controversy should dominate all sessions On arrival, registrants for Monday and Tuesday will receive preprints of all regular papers so that the sessions can concentrate on discussion. Session chairmen can arrange on the spot evening sessions to explore more fully the controversial questions that are often squelched.

The most meaningful communication occurs between individuals. Daily Happy Hours and inexpensive buffet lunches with common tables marked by activity will bring together old friends and provide opportunities to meet colleagues with similar interests. A data base with every registrant's local address and interests will be accessible for selective searching for like-minded individuals. Informal workshops and debates have been preplanned, and more can be initiated when somebody identifies a problem or a topic.

New friendships can be cemented through the many recreational opportunities. Discussions can be continued poolside or at nearby beaches. The theater and symphony attractions of Los Angeles and ocean sailing and swimming at Newport Beach are within 30-minute drives from Disneyland. The ladies' program will keep the family busy and available for a short vacation before or after the meeting.

Despite the expected record attendance, the meeting format ensures close personal contact among people with similar interests. The environment, facilities, activities and program have been shaped to achieve relevant communication.

Gerhard L. Hollander

PROGRAM

of the

Joint National Conference on Major Systems

Anaheim, California

October 25–29, 1971

The 40th National ORSA Meeting has been structured to provide new perspectives and horizons for the membership of the Society. As such, emphasis has been placed upon developing areas for the fruitful application of operations research and systems science. Foremost has been consideration of the major environmental crisis engulfing the United States, a crisis compounded of national cultural background, lack of control of technology, short-term planning horizons, continuing national urbanization and population growth, and the rising costs of Government at all levels.

On Wednesday, October 27, a Joint Plenary Session with distinguished speakers will set the stage for the more detailed discussions on Thursday and Friday.

On Thursday and Friday, October 28 and 29, twelve theme sessions will be conducted, each one focused on a major systems problem area. Paralleling these theme sessions will be sessions sponsored by the ORSA Technical Sections. There will also be simultaneous sessions of contributed papers.

In addition to the several papers oriented toward methodology and mathematical techniques in the two general sessions on Friday, a large number of contributed papers on these subjects have been grouped into consecutive simultaneous sessions scheduled for Thursday afternoon and Friday morning for the convenience of meeting attendees with primary interests in these areas. We believe that the informality and intimacy of the simultaneous sessions may provide greater opportunity for in-depth exchange of information on methodology than can be achieved in formal presentations. The ORSA Program Committee will also assist attendees with common interests who wish to organize ad hoc symposia or workshops at the meeting.

On Tuesday night, October 26, a special session on "The System Scientist and the Changing Job Market" will be jointly sponsored by the conference and the Los Angeles Council of the IEEE. This session will be open to all members of both sponsoring societies, including interested non-registrants as well as conference registrants.

This meeting is characterized by a high degree of participation of non-ORSA members, individuals working in these key problem areas. It is hoped that their definition of some of the major problems will stimulate increased participation by professional operations researchers.

REGISTRATION INFORMATION

Registration

The Registration Desk will be located at

(1) Disneyland Hotel Sierra Tower in the areas around the inside first floor elevators, on

Sunday, October 24	6:00 p.m. to 10:00 p.m.
Monday, October 25	7:30 a.m. to 5:00 p.m.
Tuesday, October 26	7:30 a.m. to 5:00 p.m.
Tuesday, October 26	6:00 p.m. to 10:00 p.m.
Thursday, October 28	7:30 a.m. to 5:00 p.m.
Friday, October 29	8:00 a.m. to 2:00 p.m.

(2) Anaheim Convention Center, in the South Lobby, between the Santa Ana Room and the Anaheim Room, on

Wednesday, October 27	7:30 a.m. to 5:00 p.m.

The Registration Desk will accommodate pre-registered and unregistered delegates.

Fees for registration and various functions are as follows (note the discount if attendees pre-register):

Sessions	Pre-registration (Money Rec'd Before 10/10/71)		Registration (At Conference)		Full-Time Students with I.D.
	Non-Member	Member	Non-Member	Member	
IEEE – 3 Days	$35.00	$25.00	$40.00	$30.00	$5.00
ORSA – 3 Days	$35.00	$25.00	$40.00	$30.00	$5.00
Combined – 5 Day	$45.00	$35.00	$50.00	$40.00	$5.00

Wednesday night banquet $10.00 if included in pre-registration; $15.00 at Conference. Buffet luncheons for $2.50 (tax and gratuities included) will be available Monday, Tuesday, Thursday and Friday at Poolside Disneyland Hotel with tickets sold *only* at the door, each of these days. The Thursday Buffet will be the Lanchester Prize Luncheon. A similar buffet lunch has been arranged for Wednesday at the Anaheim Convention Center.

Pre-registration

Pre-registration is strongly encouraged. Pre-registration with payment received by October 10, 1971, results in a $5.00 discount from registration fees at the conference. The fees are described above. A pre-registration form is attached. Please make money order or check (no cash) payable to IEEE/ORSA Joint National Conference on Major Systems. Send to Conference Registration Committee, Joint National Conference on Major Systems (ORSA/IEEE), P.O. Box 4366, Anaheim, California 92803. In returning the registration form members are requested to complete the Interest Profile and to indicate which special events they plan to attend.

Accommodations

The Disneyland Hotel, Anaheim, California, is the official headquarters and meeting hotel. A block of rooms has been reserved for attendees. Daily rates are indicated on the attached hotel registration form. To reserve a room, mail the attached form directly to the Disneyland Hotel.

All registrants may park free at the Disneyland Hotel. Free bus transportation will be provided between the Hotel and the Convention Center Tuesday night and all-day Wednesday.

The Disneyland Hotel is located adjacent to the world-famous Disneyland Amusement Park, and is easily accessible from Los Angeles International Airport by car (35 miles via San Diego and Garden Grove Freeways) or in one hour by regular airport bus service ($2.95 each way) departing twice hourly, on the hour and half-hour. West Coast and Rocky Mountain State attendees may find air service to Orange County (Santa Ana) airport available, reducing the distance to 10 miles. Orange County Airport is served by Air West, Air California, and Golden West Airlines.

SPECIAL FUNCTIONS

Dining and Relaxing

A number of Patio Buffet Lunches and No-Host Mixers have been planned to encourage informal and more personal dialogue. The Patio Buffets are scheduled beside the pool at the Disneyland Hotel for Monday, Tuesday, Thursday, and Friday. These buffets will be open 12:00 to 1:30 P.M. each day. Announcement of the Lanchester Prize will be a highlight of the Thursday Patio Luncheon.

A wine tasting party beside the pool at the Disneyland Hotel initiates the evening relaxation on Monday, October 25, 5:30 to 7:00 P.M. Several of California's finest vintners have agreed to participate, so a wide variety of wines will be available for sampling. A set-up cost of $1.00 will be charged.

On Tuesday, 4:00 to 6:00 P.M. the IEEE is emphasizing informality at their Paper Fair in the Embassy Room of the Disneyland Hotel. Cocktails will be provided nearby on a no-host basis. A no-host mixer is also planned for Thursday, 5:00 to 7:00 P.M. beside the pool at the Disneyland Hotel.

On Wednesday, all activities move to the Anaheim Convention Center. At Noon, 12:00 - 1:30 P.M., a buffet lunch will be served in the Santa Ana Room for $2.75. A no-host cocktail party is planned for 5:30 to 7:30 P.M., also in the Santa Ana Room. The Banquet of the Joint National Conference, featuring a major speech on the conference theme, will follow the cocktail party, at 7:30 P.M. Cost is $10.00 if the ticket is purchased through pre-registration; or $15.00 at the conference. The Banquet is the only food event where purchase of a ticket in advance is required.

Special Event Tours

Special tours to local places of interest are planned for conference attendees and their guests. Most tours will start approximately 10:00 A.M., but further details on starting time and place will be posted near the registration desk.

Monday, 25 October

Lion Country Safari

An African Safari bus tour through a natural habitat containing free-roaming specimens such as lions, tigers, zebras, giraffes, and other rare exotic animals.
The tour includes transportation to and from the Disneyland Hotel and admission; luncheon and snacks are not included in the cost.

Tuesday, 26 October

Ports O' Call

Transportation will be provided to the Long Beach Harbor area where an interesting waterfront setting has been created including numerous shops, restaurants and attractions. The tour includes transportation and a luncheon in the Ports O' Call Restaurant with adequate time to browse the unique shops and areas of interest.

Wednesday, 27 October

Fashion Island Shopping Center and Newporter Inn Luncheon

A shopping spree in one of the country's most beautiful centers overlooking the Pacific. Includes such famous department stores as Robinson's, Buffums, Desmonds, Broadway and 56 other shops. Unsurpassed architecture and landscaping. Luncheon for the group will be served in a restaurant nearby. Transportation and luncheon are included in the cost.

Thursday, 28 October

Disneyland Guided Tour

This event includes a visit to famous Disneyland led by Park hostesses to six of the major attractions within Disneyland. Also, additonal admission is provided to rides of your choice. Luncheon and snacks are separate. This tour is within walking distance of the hotel but will be scheduled to take advantage of the group rate.

Friday, 29 October

Knott's Berry Farm and the Movieland Wax Museum

Knott's have assembled their "Ghost Town" from the remains of early frontier gold mining towns. The area now includes numerous curio shops, rides and attractions in the theme of the old frontier days, as well as their famous berry pies. Luncheon will be served during the tour. Following the Knott's Berry Farm tour, the group will proceed to nearby Movieland Wax Museum, which contains lifelike sculptures of 100 stars, including the Palace of the Living Arts, where famous paintings are recreated into wax figures. Transportation and luncheon are both included.

Package A: Monday, Tuesday, and Wednesday tours — $13.00

Package B: Wednesday, Thursday, and Friday tours — $20.00

Package C: Includes all five tours — $30.00

Individual tours will be available, but not at the discount prices above, as follows:

Monday:	$5.90	Safari
Tuesday:	$7.00	Ports O' Call
Wednesday:	$8.50	Fashion Island
Thursday:	$6.50	Disneyland
Friday:	$7.40	Knott's Berry Farm

EXHIBITS AND DISPLAYS

Exhibits and displays of interest to ORSA members will be located in the Embassy Room at the Disneyland Hotel Tuesday, Thursday, and Friday. Exhibits will also be displayed at the Anaheim Convention Center during activities on Wednesday.

COPIES OF PAPERS

Requests for copies of papers should be sent directly to the authors and not to the committee for the meeting, the session chairmen, or the editor of the Bulletin.

WARDROBE SUGGESTIONS FOR OCTOBER IN SOUTHERN CALIFORNIA

Disneyland USA is inland from the ocean approximately 25 miles, and, therefore, has a desert climate. The days are hot, but the nights cool. October is classified as a "warm" month, the last one before the rainy season begins in November.

Day-time temperatures usually range between 70 and 80 degrees; but after sunset, the desert breezes take over and the nights are cool with temperatures in the 50s. A wrap of some kind for the ladies and a jacket for the men is necessary for evening comfort.

People in Southern California dress casually. This is interpreted as a license for almost any type of informal attire.

MESSAGE CENTER

Messages for attendees can be transmitted by calling area code (714) 533-0330. The actual physical location of the message center will be announced at the meeting

SPECIAL ANNOUNCEMENTS

• PANEL ON LARGE SYSTEMS

An informal panel discussion has been organized by Professor Alan Rowe, University of Southern California, on the subject "Can Large Scale Systems be Optimized?" Expected participants include Andrew Vazsonyi, University of Southern California, Don Malcolm, RAC, Glen Graves, UCLA, and Carl Hamilton, University of Southern California. This session is scheduled for 10:00 A.M. Wednesday, October 27, 1971, in the Pacific Room.

• CAREER COUNSELING SESSION

For the benefit of ORSA members, a special career counseling session, entitled, "Your Career in the 70's· It's Up to You," will be held on Wednesday, October 27, in the Pacific Room of the Disneyland Hotel from 2.00 to 5:00 p.m.

This session addresses the changes which are forced upon the Operations Research and Technical Professional by the changing economy. The objective of this session is to pinpoint practical solutions and outline an optimum marketing approach for individuals seeking jobs. The speakers in this session, representing a variety of industries and government, will give insight into the employer's needs, expectations, selection and hiring criteria.

Presiding will be Eva M. June, of Ability Search, Washington, D.C. There will be five presentations by experts in the field, as follows:

CHANGING PERSONNEL REQUIREMENTS FOR OR/MIS IN INDUSTRY AND THE PUBLIC SECTOR – HERBERT HALBRECHT, President, Halbrecht Associates, Inc., Greenwich, Connecticut.

EFFECTIVE UTILIZATION OF MANPOWER RESOURCES: NEW PROGRAMS – KAYE KIDDOO, Corporate Director of Manpower Resources, Lockheed Aircraft Corporation, Burbank, California.

TRANSITION FROM AEROSPACE/DEFENSE TO GENERAL AND PUBLIC SECTOR CONSULTING – LEON J. ROSENBERG, Chief Executive, Practical Concepts, Inc., Washington, D.C.

THE CHALLENGE OF THE 70'S – MAKING KNOWLEDGE PRODUCTIVE –

DR. HOWARD BERGER, Manager, Operations Research, Xerox Corporation, Rochester, New York.

MANPOWER FOR ENVIRONMENTAL PROTECTION IN THE 70'S – WILLIAM B. PARSONS, Manpower Task Force, Office of the Administrator, Environmental Protection Agency, Rockville, Maryland and MICHAEL SENEW, Manpower Specialist, Office of Manpower Development, Office of Air Programs, Research Triangle Park, North Carolina.

Following this there will be a summary of key points including how to prepare a resume which will work for you instead of against you; how to select and approach hiring companies; the do's and don'ts of a personal interview, dramatized by live and video-taped interviews directed by the session chairman.

• BANQUET

The Banquet of the Joint National Conference will be held on Wednesday, October 27, at 7:30 P.M. in the Orange County Room of the Anaheim Convention Center. Dr. Ivan A. Getting, President of the Aerospace Corporation, El Segundo, will speak on "Roles of Research and Development in Modern Society".

JOINT NATIONAL CONFERENCE ON MAJOR SYSTEMS

1971 SYMPOSIUM—IEEE SYSTEMS, MAN AND CYBERNETICS GROUP

SUMMARY OF EVENTS

	Monday, 25 October		
MA1	Opening Ceremonies	9:00–9:30 AM	Magnolia Room
MA2	Plenary Session – Civil, Urban and Social Systems	9:30–12:00 AM	Magnolia Room
MP1	Pattern Recognition and Artificial Intelligence – I	1:30–3:15 PM	Balboa Room
MP2	Modelling and Simulation – I Physical and Engineering Systems	1:30–3:15 PM	Pacific Room
MP3	Man in the System	1:30–3:15 PM	Conference Room 10
MP4	Pattern Recognition and Artificial Intelligence – II	3:30–5:00 PM	Balboa Room
MP5	Macro Systems Theory	3:30–5:30PM	Pacific Room
MP6	Information Systems and Displays – I	3.30–5:00 PM	Magnolia B
MP7	National Health Goals Workshop	1:30–4:30 PM	Conference Room 6
MP8	Decision Analysis Workshop	7:30–10:30 PM	Balboa Room
	Tuesday, 26 October		
TUA1	Plenary Session–Health Care Systems	9:00–12:00 AM	Magnolia C & D
TUA2	Highway Transportation	9:00–10:30 AM	Magnolia B
TUA3	Cybernetics and Large Systems	10:30–12.00	Pacific Room

TUA4	Environmental Quality Workshop	9:00–12:00 AM	Balboa Room
TUP1	Biological and Adaptive Systems	1:30–3:00 PM	Pacific Room
TUP2	Modelling and Simulation–II Biological, Economic and Social Systems	1:30–3:30 PM	Magnolia C & D
TUP3	Techniques for Civil, Social and Urban Systems	1:30–4:00 PM	Magnolia B
TUP4	Information Systems and Displays – II	1:30–3:00 PM	Balboa Room
TUP5	IEEE Paper Fair*	3:30–5:30 PM	Embassy Room
Special Session	The Systems Scientist and the Changing Job Market	8:30–10:30 PM	Anaheim Conv. Ctr.

Wednesday, 27 October

WA1	Joint Plenary Session I– Systems Problems of the 70's	9·30–12:30 a.m. B-187	Anaheim Conv.Ctr.
WA2	Workshop on Possibilities and Limitations of Artificial Intelligence	9:00–12:00 AM	Balboa Room
WP1	Joint Plenary Session II– Systems Problems of the 70's	2:00–5:00 p.m. B-187	Anaheim Conv. Ctr.
WP2	Pattern Recognition Workshop	1:30– 4:30 PM	Balboa Room
Banquet		7:30 PM	Anaheim Conv. Ctr.

*Papers identified as (SP) in each of the other sessions will also be included in the Paper Fair.

40th NATIONAL ORSA MEETING

SUMMARY OF EVENTS

	Wednesday, October 27	Time	Page Nos.*	Room
WA1	Joint Plenary Session I– Systems Problems of the 70s	9:30–12:30 a.m.	B-187	Anaheim Conv. Ctr.
WA3	Can Large Scale Systems be Optimized?	10:00–12:00 AM		Pacific Room
WP1	Joint Plenary Session II– Systems Problems of the 70s	2:00– 5:00 p.m.	B-187	Anaheim Conv. Ctr.
WP3	Your Career in the 70's: It's Up to You	2:00– 5:00 PM		Pacific Room
Banquet		7:30 p.m.		Anaheim Conv. Ctr.
	Thursday, October 28	**A.M.**		
THA1	The Environmental Crisis– Orchestrating Technology with Other Means to Solve Societal Problems	9:00–12:00	B-188	Magnolia C
THA2	Problems of Major Systems– Crime and Police Activities	9:00–12:00	B-189	Balboa
THA3	New Horizons in Systems Science, A Panel Discussion	9:00–12:00	B-190	Magnolia B
THA4	Cost Effectiveness Session– Computer and Telecommunications Techniques in Developing Nations	9:00–12:00	B-190	Pacific
THA5	Transportation Sciences Session– Transportation Planning	9:00–12:00	B-190	Conference Room 6
THA6	Space Sciences Sessions–Changing Roles under Confrontation	9:00–12:00	B-191	Conference Room 10
SS1	Paper Fair I: A–Urban & Education	9:00–11:00	B-202	Embassy
	B–Soc. Sci. & Military	11:00– 1:00	B-205	Embassy
Lanchester Prize Luncheon		12:30		Disneyland Poolside
	Thursday, October 28	**P.M.**		
THP1	The Environmental Crisis– Urban Problems	2:00– 5.00	B-192	Magnolia C
THP2	Problems of Major Systems– Justice and The Courts, A Panel Discussion	2:00– 5:00	B-192	Magnolia B
THP3	Problems of Major Systems– The Post Office	2:00– 5:00	B-193	Balboa
THP4	Cost Effectiveness Session– Evaluating Regional Development Programs	2:00– 5:00	B-193	Conference Room 10

*Page numbers show location of Session Programs.

	Thursday, October 28	Time	Page Nos.*	Room
THP5	Transportation Sciences Session—Highway Safety Planning, A Panel Discussion	2:00– 5:00	B-194	Pacific
THP6	Military Applications Session—DD963, A Major System	2:00– 5:00	B-194	Conference Room 6
SS2	Paper Fair 2: A—Methodology	1:00– 3:00		Embassy
	B—Health, Finance, Misc.	3:00– 5:00	B-210	Embassy
	Friday, October 29	**A.M.**		
FA1	The Environmental Crisis—Ecological Management	9:00–12:00	B-195	Magnolia C
FA2	Ethical Use of Technology—The Moral Implications of Operations Research and Engineering, A Panel Discussion	9:00–12:00	B-195	Magnolia B
FA3	General Session I—Contributed Papers	9:00–12:00	B-196	Conference Room 6
FA4	Educational Sciences Session—Educational Planning in the 70s	9:00–12:00	B-197	Conference Room 10
FA5	Military Applications Session—Panel Discussion on Group Judgment Technology Including Delphi	9:00–12:00	B-197	Pacific
FA6	Health Applications Session—Applications of OR Techniques to Medical Decisions	9:00–12:00	B-198	Balboa
SS3	Paper Fair 3 A—Methodology	9:00–11:00	B-212	Embassy
	B—Methodology	11:00– 1:00	B-215	Embassy
	Friday, October 29	**P.M.**		
FP1	Problems of Major Systems—The Resource Allocation Decision, A Panel Discussion	2:00– 5:00	B-198	Magnolia C
FP2	Management of Operations Research, A Panel Discussion	2:00– 5:00	B-199	Magnolia B
FP3	General Session II—Contributed Papers	2:00– 5:00	B-199	Balboa
FP4	Joint Session—Cost Effectiveness and Transportation Sciences	2:00– 5:00	B-200	Conference Room 10
FP5	Urban Sciences Session—Current Applications of OR to Urban Service Systems	2:00– 5:00	B-200	Conference Room 6
FP6	Health Applications Session—Application of OR Techniques to Large Scale Medical Program Planning	2:00– 5:00	B-201	Pacific
FP7	Special Student Session	2:00– 5:00	B-202	Press
SS4	Paper Fair 4: A—Ecology & Public Utility	1:00– 3:00	B-217	Embassy

*Page numbers show location of Session Programs.

BUSINESS MEETING SCHEDULE

ORSA Council	Press Room	5 p.m.–10 p.m.	Tues.	Oct. 26
		8 a.m.–10 p.m.	Wed.	Oct. 27
		8 a.m.–10 p.m.	Thu.	Oct. 28
		8 a.m.–Noon	Fri.	Oct. 29
Cost Effectiveness Section	Conf. Rm. 10	5 p.m.–7 p.m.	Thu.	Oct. 28
Military Applications Section	Conf. Rm. 6	5 p.m.–7 p.m.	Thu.	Oct. 28
Transportation Sciences Section	Pacific	5 p.m.–7 p.m.	Thu.	Oct. 28
Space Sciences Section	Conf. Rm. 5	5 p.m.–7 p.m.	Thu.	Oct. 28
Western Section ORSA	Conf. Rm. 6	8 p.m.–10 p.m.	Thu.	Oct. 28
Health Applications Section	Pacific	Noon–2 p.m.	Fri.	Oct. 29
Educational Sciences Section	Conf. Rm. 10	Noon–2 p.m.	Fri.	Oct. 29
Urban Sciences Section	Conf. Rm. 6	Noon–2 p.m.	Fri.	Oct. 29

OTHER ROOM ASSIGNMENTS

Local Arrangements Office ..... Conference Room 9
Speakers Lounge and ORSA Program Office ..... Magnolia A
Registration Committee Office ..... Regency Room

*Section Business Meetings will be convened at the starting time indicated above and generally occupy 30 to 45 minutes. Section Executive Meetings will follow. Exceptions to the above will be announced at the meeting.

PROGRAM

of the

Joint National Conference on Major Systems

Anaheim, California

October 25–29, 1971

PROGRAM

of the

1971 Symposium

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IEEE Systems, Man and Cybernetics Group

October 25–27, 1971

MONDAY AM, 25 OCTOBER — Magnolia Room

Session: MA1 9:00–9:30
Opening Ceremonies

MONDAY AM, 25 OCTOBER — Magnolia Room

Session: MA2 9:30–12:00
Civil, Urban and Social Systems

MA2.1 **A Macro-System Analysis of the Human Environment,** *KAN CHEN, Department of Environmental Systems, University of Pittsburgh, Pittsburgh, Pennsylvania 15213 (P)*

MA2.2 **The Analysis of Governmental Structures in Urban Systems,** *F.N. BAILEY, Department of Electrical Engineering, and R.T. HOLT, Department of Political Science, University of Minnesota, Minneapolis, Minnesota 55455 (P)*

MA2.3 **Systems Analysis in Solid Waste Management Planning,** *H. S. RAO, M. H. RICHARDSON, and D. A. WISMER, Systems Control, Inc., Palo Alto, California 94306 (P)*

MA2.4 **Ventura County–A Laboratory of Criminal Justice,** *M. G. KING, Ventura Subregion Council on Criminal Justice, Ventura, California 93003 (SP)*

MA2.5 **Digital Simulation of an Existing Water Resources System,** *AUGUSTINE J. FREDRICH, The Hydrologic Engineering Center, U.S. Army Corps of Engineers, Davis, California 95616 (P)*

MA2.6 **Panel Discussion:** *Future Problems in Applying Systems Engineering Techniques to Civil, Social and Urban Systems.*

NOTE: All registrants for the IEEE Symposium will receive copies of the Symposium Proceedings containing the IEEE papers marked (P); papers marked (SP) will also be included in the Paper Fair (session TUP5).

MONDAY PM, 25 OCTOBER **Balboa Room**

Session: MP1 1:30–3:15
Pattern Recognition and Artificial Intelligence I

MP1.1 **A Geometric Algorithm for Cluster Examination,** *D. V. MILOJKOVIC, C. C. TAPPERT, and A. J. GOETZE, Department of Electrical Engineering, North Carolina State University, Raleigh, North Carolina 27607 (P)*

MP1.2 **The Efficient Representation of Functions for Pattern Classification and Feature Selection,** *WILLIAM. S. MEISEL, Technology Service Corporation, Santa Monica, California 90401 (P)*

MP1.3 **Application of the Hadamard Transform in Pattern Recognition and Image Processing,** *MARTIN A. AGULNEK and RAYMOND M. KLINE, Department of Electrical Engineering, Washington University, Saint Louis, Missouri 63130 (P)*

MP1.4 **The Use of Decision Directed Learning in a Class of Pattern Recognition Problems,** *K. SHANMUGAN, School of Electrical Engineering, Oklahoma State University, Stillwater, Oklahoma 74074 (P)*

MONDAY PM, 25 OCTOBER **Pacific Room**

Session: MP2 1:30–3:15
Modeling and Simulation I – Physical and Engineering Systems

MP2.1 **Optimal Model-Following Simulation For A Set of Related Systems,** *JAMES H. BURGHART, Department of Electrical Engineering, State University of New York at Buffalo, Buffalo, New York 14214 (P)*

MP2.2 **Design of Observers with Z-Transforms and Root Locus Techniques,** *L. K. TIMOTHY, Department of Electrical Engineering, University of Utah, Salt Lake City, Utah 84112 (SP)*

MP2.3 **Dynamic Control of Industrial Systems Described by Mathematical Program Models,** *E. DUDNIKOV, Institute of Management Problems, Academy of Sciences, Moscow, U.S.S.R. (P)*

MP2.4 **Ship Systems for the Seventies: A Systems Engineering Viewpoint,** *S. MAZURSKY, Litton Ship Systems, Culver City, Calif. 90009 (P)*

MONDAY PM, 25 OCTOBER **Conference Room 10**

Session: MP3 1:30–3:15
Man in the System

MP3.1 **Modeling Man-Machine Control Systems in Biodynamic Environments,** *HENRY R. JEX, Systems Technology, Inc., Hawthorne, California 90250 (P)*

MP3.2 **Supervisory Remote Control: Space Teleoperators and Medical Telediagnosis,** *THOMAS B. SHERIDAN, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139 (SP)*

MP3.3 **A Control-Theory Model for Human Decision-Making,** *WILLIAM H. LEVINSON, Bolt Beranek and Newman, Inc., Cambridge, Massachusetts 02138 (P)*

MP3.4 **A Dynamic Model of the Human Postural Control System,** *J. C. HILL, School of Engineering, Oakland University, Rochester, Michigan 48063*

MP3.5 **An ECG Synthesizer for Arrhythmia Analysis,** *PETER SCOTT, Department of Electrical Engineering and Engineering Sciences, State University of New York at Buffalo, Buffalo, New York 14214 (SP)*

MONDAY PM, 25 OCTOBER Balboa Room

Session: MP4 3:30–5:00
Pattern Recognition and Artificial Intelligence II

MP4.1 **Fuzzy Logic Approach to Handwritten Character Recognition Problem,** *PEPE SIY and C S. CHEN, Department of Electrical Engineering, The University of Akron, Akron, Ohio 44304 (P)*

MP4.2 **Descriptive Representation of Remotely Sensed Image Data,** *O. FIRSCHEIN and M A. FISCHLER, Lockheed Palo Alto Research Laboratory, Palo Alto, California 94304 (SP)*

MP4.3 **Evaluating Feature Spaces for the Two Class Problem,** *GEORGE A. BUTLER, Allstate Insurance Company, Judson Branch Research Center, Menlo Park, California 94025 (P)*

MP4.4 **Feature Extraction in Images,** *CHARLES A. HARLOW, JACQUELINE L OTTO, Electrical Engineering Department; DAVID HALL, and G. S. LODWICK, Department of Radiology, University of Missouri-Columbia, Columbia, Missouri 65201 (P)*

MONDAY PM, 25 OCTOBER Pacific Room

Session: MP5 3:30–5:30
Macro Systems Theory

MP5.1 **Mathematical Models of Large Systems,** *GEORGE A. BEKEY, University of Southern California, Los Angeles, California 90007 (P)*

MP5.2 **The Optimization of Complex Systems with Respect to Multiple Criteria,** *ROBERT M. BEESON, Xerox Data Systems, El Segundo, California 90245, and WILLIAM S MEISEL, Technology Service Corporation, Santa Monica, California 90401 (P)*

MP5.3 **Equitability in Multi-Agent Dynamic Systems: The Case of m Agents and n^m States,** *DAVID W. PETERSON, Northwestern University, Graduate School of Management, Evanston, Illinois 60201 (SP)*

MP5.4 **Structural Decomposition and Control of Complex Systems,** *DAVID C. COLLINS, Technology Service Corporation, Santa Monica, California 90401 (P)*

MP5.5 **A New Methodology for the Hierarchical Grouping of Related Elements of a Problem,** *S. F. LOVE, Faculty of Technology, University of Guyana, Guyana, South America (SP)*

MP5.6 **Predictability of Transient and Steady-State Behavior in a Class of Complex Binary Nets,** *C C WALKER, Department of Industrial Administration, University of Connecticut, Storrs, Connecticut 06268 (SP)*

MONDAY PM, 25 OCTOBER Magnolia B

Session: MP6 3:30–5:00
Information Systems and Displays I

MP6.1 **Artificial Intelligence and Large Interactive Man Computer Systems,** *JAIME R. CARBONELL, Bolt Beranek and Newman, Inc., Cambridge, Massachusetts 02138 (P)*

MP6.2 **Interactive Computer Graphics, A Simulation Tool,** *CHARLES G. FRANKHAUSER and ROBERT H. KIDWELL, The Johns Hopkins University, Applied Physics Laboratory, Silver Spring, Maryland 20910 (P)*

MP6.3 **A Computer-Aided Environment for Systems Design,** *JULIAN REITMAN, Norden Division, United Aircraft Corporation, Norwalk, Connecticut 06856 (SP)*

MP6.4 The Los Angeles Fire Department Command and Control System, *GARY E. BOYD, Public Safety Systems, Inc., Santa Barbara, California 93105 (P)*

MONDAY PM, 25 OCTOBER Conference Room 6

Session: MP7 1:30–4:30
National Health Goals Workshop
Organizer: RAPHAEL J. SALMON

MONDAY PM, 25 OCTOBER Balboa Room

Session: MP8 7:30–10:30
Decision Analysis Workshop

TUESDAY AM, 26 OCTOBER Magnolia C&D

Session: TUA1 9:00–12:00
Health Care Systems

TUA1.1 Towards Establishment of National Goals for Medical and Health Services in the U.S., *RAPHAEL J. SALMON, Department of Urban Studies and Community Development, Rutgers University, The State University of New Jersey, Camden, New Jersey 08102 (P)*

TUA1.2 Planning of a Health Care System Modeled as a Two Person Game, *EDWARD A. MATROSE and RANGASWAMY MUKUNDAN, Department of Electrical Engineering, Clarkson College of Technology, Potsdam, New York 13676 (SP)*

TUA1.3 Building a Health Information System for Los Angeles County, *ANN H. COULSON, VIRGINIA A. CLARK, and JOHN M. CHAPMAN, Department of Preventive and Social Medicine, UCLA School of Medicine, UCLA Center for the Health Sciences, Los Angeles, California 90024 (P)*

TUA1.4 Computer Systems in Medicine, *MORTON D. SCHWARTZ, Electrical Engineering Department, California State College, Long Beach, California 90801 (P)*

TUA1.5 A Computer Based Medical Information System, *HARLAN E. FRETHEIM and ELAINE E. NUSSBAUM, Medical Systems Research Laboratory, Control Data Corporation, Burlington, Vermont 05401 (P)*

TUA1.6 Panel Discussion: *Future of Health Care Systems*

TUESDAY AM, 26 OCTOBER Magnolia B

Session: TUA2 9:00–10:30
Highway Transportation

TUA2.1 A Planting Method for Regional Road Investments, *LEON D. CHAPMAN, School of Electrical Engineering, Center for Systems Science, Oklahoma State University, Stillwater, Oklahoma 74074 (P)*

TUA2.2 Surveillance and Control for a System of Parallel Roadways, *K. W. DODGE and R. A. REISS, Sperry Rand Corporation, Sperry Systems Management Division, Great Neck, New York 11020 (P)*

TUA2.3 Some Simulation Results of Different Vehicular Traffic Control Strategies, *P.I. MUNJAL and YUAN-SHIH HSU, System Development Corporation, Santa Monica, California 90406 (P)*

TUESDAY AM, 26 OCTOBER **Pacific Room**

Session: TUA3 10:30–12:00
Cybernetics and Large Systems

TUA3.1 **Realization of a Data Independent Pattern Recognition System Based on Human Physiology,** *M. KABRISKY, Air Force Institute of Technology; and J. W. CARL, Air Force Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio 45433 (P)*

TUA3.2 **Finite-State Machines as Elements in Control Systems,** *GEORGE H. BURGIN and MICHAEL J. WALSH, Decision Science, Inc., San Diego, California 92109 (P)*

TUA3.3 **A Cybernetical Model of Man in His Cultural Environment,** *FRED J. RICCI, The Mitre Corporation, McLean, Virginia 22101 (SP)*

TUA3.4 **Stability Analysis of a Class of Nonlinear Deterministic Neural Networks,** *NEIL M. BRANSTON, Department of Electrical Engineering, Rice University, Houston, Texas 77001 (SP)*

TUA3.5 **Cybernetic Functionals,** *H. BREMERMANN, University of California, Berkeley, Calif. 94720 (P)*

TUESDAY AM, 26 OCTOBER **Balboa Room**

Session: TUA4 9:00–12:00
Environmental Quality Workshop
Organizer: J. L. UHRIG

TUESDAY PM, 26 OCTOBER **Pacific Room**

Session: TUP1 1:30–3:00
Biological and Adaptive Systems

TUP1.1 **Pattern Identification by Spatial Filtering in Neuron Network Model,** *CHARLES J. SWIGERT, TRW Systems Group, Redondo Beach, California 90278 (P)*

TUP1.2 **Spatial Information Processing in the Brain,** *THOMAS W. CALVERT, FRANK MENO, and KENG-CHIANG YANG, Electrical Engineering Department and Biotechnology Program, Carnegie-Mellon University, Pittsburgh, Pennsylvania 15213 (P)*

TUP1.3 **An Evaluation of Learning Automata and Related Sampling Approaches to Optimal-Choice Problems,** *I. JOSEPH SHAPIRO, Bell Telephone Laboratories, Whippany, New Jersey 07981 (SP)*

TUP1.4 **On Invariant Imbedding and Maximum Likelihood Adaptive Estimation,** *ANDREW P. SAGE and CHARLES D. WAKEFIELD, Information and Control Sciences Center, SMU Institute of Technology, Dallas, Texas 75222 (P)*

TUESDAY PM, 26 OCTOBER Magnolia C&D

Session: TUP2 1:30–3:30
Modeling and Simulation II – Biological, Economic and Social Systems

TUP2.1 **A Common Model in Socio-Economics, Ecology and Physiology,** *R. R. MOHLER, Information and Computing Sciences, University of Oklahoma, Norman, Oklahoma 73069 (P)*

TUP2.2 **An Approach to a Cybernetic Model of Man for Use in Social Systems Simulation,** *WILLIAM B. GEVARTER, National Aeronautics and Space Administration, Washington, D.C. 20546 (SP)*

TUP2.3 **Some Models of Planning and Control in a System of Training of Specialists,** *M.A. BERMANT, L.K. SEMJONOV, and V.N. SALITSKIJ, U.S.S.R. (P)*

TUP2.4 **Simulation Experiments with a Biomanagement Model of a Deer Herd,** *F. M. ANDERSON, A.N. HALTER, Department of Agricultural Economics, Oregon State University, Corvallis, Oregon 97331; G.E. CONNOLLY, and W.M. LONGHURST, Department of Agricultural Zoology, University of California at Davis, Davis, California 95616 (P)*

TUP2.5 **A Development Planning-Oriented Simulation Model of the Agricultural Economy of Southern Nigeria,** *MICHAEL H. ABKIN and THOMAS J. MANETSCH, Department of Agricultural Economics, Michigan State University, East Lansing, Michigan 48823 (P)*

TUESDAY PM, 26 OCTOBER Magnolia B

Session: TUP3 1:30–4:00
Techniques for Civil, Social and Urban Systems

TUP3.1 **Industrial Businesses as Major Systems to be Controlled,** *HAROLD CHESTNUT, General Electric Company, Schenectady, New York 12305 (P)*

TUP3.2 **Telecommunications Systems for Group Feedback: Seven Problems of Design,** *THOMAS B. SHERIDAN, Department of Mechanical Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139 (SP)*

TUP3.3 **Analysis and Optimization of Multi-Level Inventory Control,** *DUNSTAN GRAHAM, PERSHING SUN, and NORMAN FROMM, Department of Aerospace and Mechanical Sciences, Princeton University, Princeton, New Jersey 08540 (P)*

TUP3.4 **A Mathematical Theory of Liability and Warranty for Urban and Social Systems,** *IGOR BAZOVSKY, JR., Igor Bazovsky and Associates, Inc., Sherman Oaks, California 91403 (SP)*

TUP3.5 **Clean Cars and Clean Smokestacks–A Matter of Survival,** *JAMES V. LEONARD, McDonnell Douglass Astronautics Company, Eastern Division, St. Louis, Missouri 63166; and HERBERT A. CROSBY, Department of Electrical Engineering, St. Louis Graduate Engineering Center, University of Missouri, St. Louis, Missouri 63121 (P)*

TUP3.6 **An Adaptive Learning Machine for Securities and Market Analysis,** *L.A. WAN, Sycom, Inc., Anaheim, California 92801 (P)*

TUESDAY PM, 26 OCTOBER Balboa Room

Session: TUP4 1:30–3:00
Information Systems and Displays, Part II

TUP4.1 Time Shared Test, Operation, and Repair of Corporate Fed Array Radars, *H. H. GRIMM, General Electric Company, Heavy Military Electronic Systems, Syracuse, New York 13201 (P)*

TUP4.2 Computer Simulation of the Dynamics of Large Scale Mobile Communications Systems, *D. C. COX and D. O. REUDINK, Bell Telephone Laboratories, Inc., Crawford Hill Laboratory, Holmdel, New Jersey 07733 (P)*

TUP4.3 A Top Down Analysis of Traffic Flow in a Two-Way Alternate Data Communications Link Having a Reserve Channel, *WILBURN O. CLARK and JOHN R. CLYMER, Electrical Engineering Department, Arizona State University, Tempe, Arizona 85281 (SP)*

TUP4.4 Effects of Signal Density, Update Rate, and Color Coding Upon Human Information Processing, *M. J. WYMAN, C. P. GREENING, and R. D. STURM, North American Rockwell, Electronics Group, Anaheim, California 92803 (SP)*

TUESDAY PM, 26 OCTOBER Embassy Room

Session: TUP5 3:30–5:30
IEEE Paper Fair*

TUP5.1 Systems Applications of Availability Analysis, *M. M. HOLLAND, Northrop Corporation, Electro-Mechanical Division, Anaheim, California 92801 (PF)*

TUP5.2 Toward Municipal Management Information Systems, *E. D. CUTULY, Westinghouse Tele-Computer Systems Corporation, Pittsburgh, Pennsylvania 15221 (PF)*

TUP5.3 The Sensitivity of Planning Decisions in River Basin Management, *D. T. O'LAOGHAIRE and D. M. HIMMELBLAU, E. P. Schoch Laboratories, Department of Chemical Engineering, The University of Texas at Austin, Austin, Texas 78712 (PF)*

TUP5.4 Quantification of Synergistic Effects in Business Mergers, *ROBERT W. MILIK, JR., Mineola, New York 11501 (PF)*

TUP5.5 Adaptive Transformation Networks for Modeling, Prediction, and Control, *ROGER L. BARRON, Adaptronics, Inc., McLean, Virginia 22101 (PF)*

TUP5.6 An Oceanographic System for Tsunami Detection, *H. A. TITUS and D. E. KIRK, Naval Postgraduate School, Monterey, California 93940 (PF)*

TUP5.7 Application of Business Games to Verification of Organization Control Principles, *V. SOKOLOV, Institute of Automatics & Telemechanics, U.S.S.R. Academy of Sciences, Moscow, B-485, U.S.S.R.*

*Papers identified as (SP) in each of the other sessions will also be included in the Paper Fair.

WEDNESDAY AM, 27 OCTOBER Balboa Room

Session: WA2 9:00–12:00
Workshop on Possibilities and Limitations of Artificial Intelligence
Organizer: M. S. WATANABE

WEDNESDAY PM, 27 OCTOBER Balboa Room

Session: WP2 1:30–4:30
Pattern Recognition Workshop
Organizer: E. A. PATRICK

SPECIAL SESSION

TUESDAY PM, OCTOBER 26 **Anaheim Convention Center**

Special Session: 8:00 p.m.–10:30 p.m.
The Systems Scientist and the Changing Job Market, A Panel Discussion

Moderator: MR. HERBERT Z. HALBRECHT
Halbrecht Associates, 2 Greenwich Plaza, Greenwich, Conn. 06830

Panelists:

HON. JOHN I. BURTON, Joint Legislative Economic Conversion Committee, State Assembly, Sacramento, California 95814;
DR. CARL M. YORK, Technical Assistant to the Scientific Advisor to the President, Executive Office of the President, Washington, D.C. 20506;
JAMES H. MULLIGAN, JR., President, Institute of Electrical and Electronics Engineers, 345 East 47th Street, New York, New York 10017; and
representatives of the unemployed systems scientists

The job market for the high technology professional is currently adjusting from a climate of unrealistic opportunism caused by unbalanced supply/demand and early naivete on the part of the government and employers. These latter have recently been radically adjusting their demands for professional people with much consequent unemployment in scientific fields. The professionals themselves have been hoping for reconversion to new fields, primarily systems science in the non-defense sector. What these changes are specifically–why they are coming about and the problems faced by individuals seeking to make such conversions–will be the topic of this session.

In order to allow widest attendance, there will be no charge or registration fee for attendance at this one session of the Joint National Conference on Major Systems for members of either sponsoring society.

JOINT IEEE—ORSA PLENARY SESSIONS

WEDNESDAY AM, October 27 **Anaheim Convention Center**

Session: WA 1 9:30 AM–12:30 PM
Joint Plenary Session I–
Systems Problems of the 70's

Chairman. ADMIRAL C. F. HORNE, U.S.N. (Ret.)
Consultant, General Dynamics Corp., P.O. Box 2507, Pomona, Calif. 91766

WA1.0 **Call to Order,** *G.L. HOLLANDER, General Chairman, Joint National Conference on Major Systems, & Hollander Associates, P.O. Box 2276, Fullerton, California 92633*

WA1.1 **Welcome Address,** *ADMIRAL C.F. HORNE, U.S.N. (Ret.), General Dynamics Corp., P.O. Box 2507, Pomona, California 91766*

WA1.2 **Systems Problems in the City,** *PETER SZANTON, Director, New York City–Rand Institute, 545 Madison Avenue, New York, New York 10022*

WA1.3 **Managing Technology Transfer,** *F.G. RODGERS, VICE PRESIDENT and CORPORATE DIRECTOR of MARKETING, IBM Corp., Armonk, N.Y. 10504*

WEDNESDAY PM, October 27 **Anaheim Convention Center**

Session: WP1 2:00 PM–5:00 PM
Joint Plenary Session II–
Systems Problems of the 70's

Chairman: S. M. GREENFIELD, Asst. Administrator for Research and Monitoring, Environmental Protection Agency, 1626 K Street, N.W., Washington, D.C. 20460

WP1.1 **The Global Environmental Crisis,** *GORDON J.F. MacDONALD, Council on Environmental Quality, 722 Jackson Place, N.W., Washington, D.C. 20506*

WP1.2 **Managing for a Better Environment,** *S.M. GREENFIELD, Environmental Protection Agency, 1626 K Steet, N.W., Washington, D.C. 20460*

WP1.3 **The California Tomorrow Plan,** *HARVEY PERLOFF, Dean, School of Architecture and Urban Planning, University of California, Los Angeles, CA 90024*

WP1.4 **The Role of Education for Environmental Management,** *DANIEL G. ALDRICH, JR., Chancellor, University of California, Irvine, California 92664*

PROGRAM

of the

40th National Meeting

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Operations Research Society of America

DISNEYLAND HOTEL ANAHEIM, CALIFORNIA

October 28–29, 1971

THURSDAY AM, OCTOBER 28 **Magnolia C**

Session: THA1 9:00–12:00

The Environmental Crisis–
Orchestrating Technology with Other Means to Solve Societal Problems

Chairman GABOR STRASSER
Office of Science and Technology, Executive Office of the President, Washington, D.C. 20506

Co-Chairman: ROBERT W. LAMSON
National Science Foundation, 1800 G Street, N.W., Wash. D.C. 20550

THA1.1 **Orchestrating Technology with Other Means to Solve Societal Problems,** *GABOR STRASSER, Officer of Science and Technology, Executive Office of the President, Washington, D.C. 20506.*

THA1.2 **Integrated Population/Environmental Policy–Needs and Constraints,** *R. W. LAMSON, National Science Foundation, 1800 G Street N W., Washington, D.C. 20550.*

THA1.3 **Social Priorities: The Dilemma of Quality vs. Quantity,** *MARTIN V. JONES, The Mitre Corporation, Westgate Research Park, McLean, Va. 22101.*

THA1.4 **Urban Transportation,** *CHARLES A ZRAKET, Senior Vice President, The Mitre Corporation, Westgate Research Park, McLean, Virginia. 22101.*

THA1.5 **The Automobile and Air Pollution–"Who Won the War?,"** *S. WILLIAM GOUSE, Associate Dean, Carnegie Mellon University, 5000 Forbes Avenue, Pittsburgh, Pa. 15213.*

THA1.6 **The Practical Application, from within the University, of Interdisciplinary Approaches to Problems of Municipalities,** *ROBERT NATHANS, Chairman Urban Science and Engineering Program, State University of New York, Stony Brook, New York 11790.*

THA1.7 **Health Care for the 1970's,** *RAPHAEL J. SALMON, Chairman, Dept. of Urban Studies, Rutgers University, South Jersey Campus, Camden, N.J. 08204.*

Abstracts: B-220

Formal presentations will be followed by a round table discussion to develop two central themes. (1) the identification of the needed intellectual and substantive tools to solve these problems with special focus on the missing elements and (2) the identification of the necessary political, institutional, and other related arrangements which are required but are presently missing. It is the hope of this session to identify a strategy for needed action to solve critical domestic social problems.

THURSDAY AM, OCTOBER 28 **Balboa**

Session: THA2 9:00–12:00
Problems of Major Systems–Crime and Police Activities

Chairman: WESLEY A. POMEROY
Director of Safety and Development, University of Minnesota, Minneapolis, Minnesota 55455

THA2.1 **Transaction Based Statistics for Criminal Justice Management Decision-Making,** *PAUL K. WORMELI, Vice President, Public Systems Inc., San Jose, Calif 95117, and STEVEN E. KOLODNEY, Public Systems Inc., 1030 S. Winchester Blvd., San Jose, Calif. 95117.*

THA2.2 **Highway Safety: Computer Applications,** *ALFRED F. LYNCH, Vice President, National Information Systems Corp., Valley Forge, Pa. 19481.*

THA2.3 **Private Police in the United States,** *JAMES S KAKALIK and SORREL WILDHORN, Rand Corporation, 1700 Main Street, Santa Monica, Calif. 90406.*

THA2.4 **Computer Assisted Dispatching Systems,** *ROBERT J. RIEDER, Director of Management Information Systems, North American Rockwell Information Systems Company (NARISCO), P.O. Box 4302, 3320 East La Palma Avenue, Anaheim, Calif. 92803.*

THA2.5 **The Applications of Operations Research to Forensic Science,** *HAIG BOHIGIAN, John Jay College of Criminal Justice, the City University of New York, 315 Park Ave. South, New York, New York 10010.*

Abstracts: B-221

THURSDAY AM, October 28 **Magnolia B**

Session: THA3 9:00-12:00
New Horizons in Systems Science, A Panel Discussion

Chairman: RICHARD BELLMAN
Department of Electrical Engineering,
University of Southern California, Los Angeles, California 90007

Co-Chairman: LOTFI ZADEH
School of Engineering, University of California,
Berkeley, California 94720

Panel: R. BELLMAN, University of Southern California, J. EATON, IBM Corporation, San Jose, California 95123, H. FRANK, Network Analysis Corporation, Great Neck, New York, R. LARSON, Systems Control, Inc., 260 Sheraton Avenue, Palo Alto, California 94306, and L. ZADEH, University of California, Berkeley, California 94720.

THURSDAY AM, October 28 **Pacific**

Session: THA4 9:00-12:00
Cost Effectiveness Session—Computer and Telecommunications Techniques in Developing Nations

Chairman: JOHN D. WILKES
Consultant, 1024 Wisconsin Avenue, Washington, D.C. 20007

Co-Chairman: ROY E. LAVE, JR.
Chairman, Dept. of Industrial Engineering,
Stanford University, Stanford, California 94305

THA4.1 **Systems Approaches for Development,** *GUY B. GRESFORD, Director for Science and Technology, United Nations, New York, New York 10017.*

THA4.2 **Computers and Data Bases as a Tool for Communications and Development,** *WILLIAM F. MILLER, Vice President and Provost, Stanford University, Stanford, California 94305.*

THA4.3 **The Role of Satellites in Telecommunications in the Developing Countries,** *BRUCE LUSIGNAN, Associate Professor of Electrical Engineering, Stanford University, Stanford, California 94305.*

Abstracts: B-222

THURSDAY AM, October 28 **Conference Room 6**

Session: THA5 9:00-12:00
Transportation Sciences Session—Transportation Planning

Chairman: FRED M. ZIMMERMAN
System Development Corp., 2500 Colorado Ave.,
Santa Monica, California 90406

Co-Chairman: NORMAN V. PETERSON
System Development Corp., 2500 Colorado Ave.,
Santa Monica, California 90406

THA5.1 **The Use of Computer Simulation In Airport Airside Planning,** *D.B. ADARKAR, Douglas Aircraft Co., 3855 Lakewood Blvd., Long Beach, Calif. 90801.*

THA5.2 **The Planning Process in the California Division of Highways,** *GEORGE WOFFORD, California Division of Highways, P.O. Box 2304, Los Angeles, California 90054.*

THA5.3 **New Transportation Concepts for Urban Growth Control,** *NORMAN V. PETERSON, System Development Corp., 2500 Colorado Ave., Santa Monica, Calif. 90406.*

THA5.4 **An Evaluation of Conventional and Interactive Planning Procedures,** *J.D. DRACHMAN, J D. Drachman Associates, 1918 Bonita Avenue, Berkeley, California 94705.*

THA5.5 **Contingency Headway Analysis for Ground Transportation Systems, An Analytical Approach,** *DAVID B. SMITH and JONATHAN S. YORMARK, Civil Systems Group, Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, California 91103.*

Abstracts: B-223

THURSDAY AM, October 28 **Conference Room 10**

Session: THA6 9:00-12:00
Space Sciences Session—Changing Roles Under Confrontation

Chairman: HAROLD HORNBY
Advanced Concepts & Mission Div., NASA Ames Research Center,
Moffett Field, California 94035

Co-Chairman: LARRY R. ALTON
Advanced Concepts & Mission Div., NASA Ames Research Center,
Moffett Field, California 94035

THA6.1 **Manned Earth Orbital Research and Applications Investigation,** *KENNETH A. STONE, Convair Aerospace Division, P.O. Box 1128, General Dynamics Corp., San Diego, California 92112.*

THA6.2 **Typical Problems in Bridging from Space Technician to User Communities,** *ALLAN MUIR, Earth Satellite Corp., 1771 N Street, N.W., Washington, D.C. 20036.*

THA6.3 **Utilization of Meteorological Satellite Data with Emphasis on the User's Needs,** *DELBERT B. SMITH, Space Science and Engineering Center, University of Wisconsin, 1225 W. Dayton Street, Madison, Wisconsin 58706.*

THA6.4 **The Economy, Technological Progress, and R&D—Some Interactions,** *ROBERT E. ROBERTS, HOWARD GADBERRY, and ROBERT E. FLEISHER, Midwest Research Institute, 425 Volker Blvd., Kansas City, Missouri 64110.*

Abstracts: B-224

Papers will be discussed by LARRY R. ALTON, NASA Ames, and ARTHUR D. ALEXANDER III of NASA. A discussion will follow moderated by RUSSELL DREW, Office of Science and Technology, Executive Office of the President, Washington, D.C. 20506.

THURSDAY PM, October 28 **Magnolia C**

Session: THP1 2:00-5:00
The Environmental Crisis—Urban Problems

Chairman: WORTH BATEMAN
Vice President, Operations, The Urban Institute,
2100 M Street, N.W., Washington, D.C. 20037

THP1.1 **Welfare Reform and the Urban Crisis,** *JODIE ALLEN, The Urban Institute, 2100 M Street, N.W., Washington, D.C. 20037.*

THP1.2 **Federal Programs and Environmental Problems in the City,** *JOHN DEUTCH, Department of Chemistry, Massachusetts Institute of Technology, Cambridge, Mass. 02139.*

THP1.3 **Systems Effects of Revenue Sharing,** *CHARLES GOETZ, Public Choice Center, Virginia Polytechnic Institute, Blacksburg, Va. 24061.*

THP1.4 **Urban Health Problems, New York City Perspective,** *ROBERT HARRIS, New York City Health Services Administration, New York City, New York 12201.*

THP1.5 **Post-Secondary Education and the City,** *ALICE RIVLIN, Senior Fellow, The Brookings Institute, 1775 Massachusetts Avenue, N.W., Washington, D.C. 20036.*

Abstracts: B-224

THURSDAY PM, October 28 **Magnolia B**

Session: THP2 2:00-5:00
Problems of Major Systems—Justice and the Courts, A Panel Discussion

Chairman: ERNEST C. FRIESEN, JR.
Institute for Court Management, University of Denver Law Center,
Denver, Colorado 80204

Co-Chairman: RALPH KLEPS
Administrative Office of the Court, 455 Golden Gate Avenue,
San Francisco, California 94102

Panelists: GEORGE KERSHAW, Institute for Court Management, Denver, Colorado 80204, and GEORGE MORGAN, Ford Foundation, New York, N.Y.

The modern court may well be one of society's most complex institutions. In addition to deciding cases, the modern court supervises juveniles and convicted persons, manages juror systems, collects and disburses large sums of money and maintains detailed, legally significant records. This panel will consider the relationship of the courts to society's concept of justice and the potential role of management science in the administration and management of the court system.

THURSDAY PM, October 28 **Balboa**

Session: THP3 2:00-5:00
Problems of Major Systems—The Post Office

Chairman: ROBERT H. COHEN
Institute for Defense Analysis, 400 Army-Navy Drive, Arlington, Virginia 22202.

Co-Chairman: THOMAS WHITE
Institute for Defense Analysis, 400 Army-Navy Drive, Arlington, Virginia 22202

THP3.1 **Problems of Major Systems: The Post Office,** *ROBERT H CCHEN and THOMAS WHITE, Institute for Defense Analysis, 400 Army-Navy Drive, Arlington, Virginia 22202.*

THP3.2 **The Postal Service and the Future Environment,** *WILLIAM J. SULLIVAN, Acting Assistant Postmaster General for Planning and Marketing, U.S. Postal Service, Washington, D.C. 20044.*

THP3.3 **The New National Bulk Mail System,** *GEORGE R. CAVELL, Program Director, National Bulk Mail Programs, Research and Engineering Department, U.S Postal Service and JERRY A. EDGERTON, Research and Engineering Dept., U.S. Postal Service, Washington, D.C. 20044.*

THP3.4 **Postal and Telephone Networks: Some Similarities and Differences,** *RONALD ABLER, The Pennsylvania State University, University Park, Pa. 16802.*

THP3.5 **Letter Mail Sorting: An Examination of Cost and Service,** *ROBERT COHEN, CHARLES McBRIDE, and THOMAS WHITE, Institute for Defense Analysis, 400 Army-Navy Drive, Arlington, Virginia 22202.*

Abstracts: B-226

THURSDAY PM, October 28 **Conference Room 10**

Session: THP4 2:00-5:00
Cost Effectiveness Session—Evaluating Regional Development Programs

Chairman: RAYMOND H. MILKMAN
United States Department of Commerce, 14th & E Streets, N.W., Washington, D.C. 20230.

THP4.1 **Evaluation of Economic Development on Indian Reservations,** *BARRY T. KIBEL, Boise Cascade Center for Community Development, 1225 Connecticut Avenue, N.W., Suite 600, Washington, D.C. 20036.*

THP4.2 **An Evaluation of Selected Growth Center Strategies for Economic Development,** *RAYMOND H. MILKMAN, Economic Development Administration, U.S. Dept. of Commerce, Washington, D.C. 20230.*

THP4.3 **An Evaluation of Selected Training Activities Designed to Stimulate Economic Development,** *HOWARD L. WALTON, Economic Development Administration, U.S. Department of Commerce, Washington, D.C. 20230.*

THP4.4 **Some Issues in the Evaluation of Rural Industrial Development Programs,** *H. LOUIS STETTLER, Chairman, Maryland Governor's Council of Economic Advisors; FREDERICK T. SPARROW and WILLIAM H. OAKLAND, Professors of Political Economy, Johns Hopkins University, Baltimore, Maryland 21218.*

Abstracts. B-227

THURSDAY PM, October 28 **Pacific**

Session: THP5 2:00-5:00
Transportation Sciences Session—Highway Safety Planning, A Panel Discussion

Chairman: P. ROBERT KNAFF
Research Institute, National Highway Traffic Safety Adm., 400 7th Street, S.W., Washington, D.C. 20044
Co-Chairman: GERALD A. FLEISCHER
Dept. of Industrial and Systems Engineering, University of So. Calif., L.A., California 90007

THP5.1 **Highway Safety Planning—A View from the Federal Level,** *CHARLES H. HARTMAN, Deputy Administrator, National Highway Traffic Safety Adm., Washington, D.C. 20044.*

THP5.2 **Highway Safety Planning—As Viewed from the State Agency Level,** *RONALD S. COPPIN, Chief, Research and Statistics, California Department of Motor Vehicles, Sacramento, California 95818.*

THP5.3 **Highway Safety Planning—The View from the University Setting,** *B.J. CAMPBELL, Director, Highway Safety Research Center, University of North Carolina, Chapel Hill, N.C. 27514*

THP5.4 **Highway Safety Planning—As Viewed by the Automotive Manufacturer,** *RICHARD E. KIMBALL, Executive Engineer-Safety Planning, Ford Motor Company, Dearborn, Michigan 48021.*

Abstracts: B-227

Subsequent to the above talks, a panel discussion will ensue moderated by Dr. KNAFF.

THURSDAY PM, October 28 **Conference Room 6**

Session: THP6 2:00-5:00
Military Applications Session—DD963, A Major System

Chairman: FRANK G. SPINNEY
Hughes Aircraft Co., Electron Dynamics Division, 3100 Lomita Blvd., Torrance, California 90505

THP6.1 **The DD-963 Class Ship, A Major System,** *FRED KOSOFSKY, Mgr. Performance Analysis Dept., Litton Systems AMTD, P.O. Box 92911, Los Angeles, California 90009.*

Abstract: B-228

Discussion will follow this major presentation.

FRIDAY AM, October 29 **Magnolia C**

Session: FA1 9:00-12:00
The Environmental Crisis—Ecological Management

Chairman: LYLE TAYLOR
Consultant, 1434 East Rio Verde Drive, West Covina, California 91709

Co-Chairman: RICHARD BALL
The Rand Corporation, 1700 Main St., Santa Monica, California 90406

FA1.1 **Total Conservation, an Evolving Concept,** *MICHAEL McCLOSKEY, Executive Director, The Sierra Club, 1050 Mills Tower, San Francisco, Calif. 94104.*

FA1.2 **The Oceans: Putting It All Together,** *WESLEY A. MARX, 18051 Butler St., Irvine, Calif. 92664.*

FA1.3 **Undesirable Feedback from Human-Modified Ecosystems,** *CHARLES F. BENNETT, University of California at Los Angeles, Los Angeles, Calif. 90024.*

FA1.4 **Modeling of a Complex Ecosystem: Lake George, New York,** *J.W. WILKINSON, School of Management and R.A. PARK, Department of Geology, Rensselaer Polytechnic Institute, Troy, New York 12181.*

FA1.5 **Collective Utility and Cost Effectiveness in Natural Resource Management,** *LUCIEN DUCKSTEIN, University of Arizona, Tucson, Arizona 85721 and EDWIN DUPNICK, NASA Manned Spacecraft Center, Houston, Texas 77008.*

FA1.6 **An Application of Systems Dynamic Modeling to Energy Systems Planning,** *JACK BYRD, JR., R. DAVID HAYNES, Department of Industrial Engineering, West Virginia University, Morgantown, West Virginia 26505; and LEO A. SCHRIDER, U.S. Bureau of Mines, Morgantown Energy Research Center, Morgantown, West Va. 26505.*

FA1.7 **Technology Assessment: Fond Hopes and Rational Expectations,** *DONALD E. CUNNINGHAM, National Science Foundation and DAVID M. GLANCY, Virginia Polytechnic Institute and State University, Blacksburg, Va. 24060.*

Abstracts: B-228

FRIDAY AM, October 29 **Magnolia B**

Session: FA2 9:00-12:00
Ethical Use of Technology—The Moral Implications of Operations Research and Engineering, A Panel Discussion

Chairman: C. WEST CHURCHMAN
Space Sciences Laboratory, University of California, Berkeley, Calif.

Panelists: C. WEST CHURCHMAN, University of California, Berkeley, Calif. 94720; FREDERICK BETZ, State University of New York, Buffalo, New York 14214; IAN MITROFF, University of Pittsburgh, Pa. 15213; A.H. SCHAINBLATT, TEMPO-General Electric Co., Santa Barbara, Calif. 93102; MICHAEL E. ECHOLS, University of Wisconsin, Milwaukee, Wisc. 53201; and RICHARD O. MASON, UCLA, Los Angeles, Calif. 90024.

This panel session will be an open discussion. The thesis will be that there is both a conceptual and a real conflict between morality and the motivation to improve society along socio-economic lines. The discussion will center on the meaning of morality, the nature of the conflict between morality and operations research, and the question whether there is a resolution of this conflict.

FRIDAY AM, October 29 **Conference Room 6**

Session: FA3 9:00-12:00
General Session I—Contributed Papers

Chairman: L.F. ELIEL
McDonnell Douglas Corp., 3855 Lakewood Blvd., Long Beach, California 90801

Co-Chairman: DAVID L. JAQUETTE
Department of Industrial & Systems Eng., University of Southern Calif., Los Angeles, California 90007

FA3.1 **Value of Quieting VTOL Aircraft,** *JOHN H. TINLEY, Hughes Tool Company, Centinela at Teale, Culver City, Calif. 90230.*

FA3.2 **Scheduling Boundary Defenses to Minimize the Number of Penetrations,** *STEPHEN BALUT and GILBERT T. HOWARD, Naval Postgraduate School, Monterey, Calif. 93940.*

FA3.3 **Attacking a Perishable Target System: A Dynamic Programming Approach,** *CLAYTON J. THOMAS and DAVID V. MASTRAN, Headquarters, United States Air Force, Washington, D.C. 20330.*

FA3.4 **Simplified Air Battle Models based on Lanchester-Type Equations,** *ROY K. FRICK, Aeronautical Systems Division, Wright-Patterson Air Force Base, Ohio 445433*

FA3.5 **Approximate Localization Theorems for Optimal Facility Placement,** *A.J. GOLDMAN, National Bureau of Standards, Washington, D.C. 20234.*

FA3.6 **Possible and Likely Futures of Urban Transportation,** *FRANCISCO SAGASTI and RUSSELL L. ACKOFF, Management and Behavioral Science Center, University of Pennsylvania, Philadelphia, Pa 19104.*

FA3.7 **A System Approach for Congestion Control in a Street Network,** *CHUAN F. WANG, Department of Civil Engineering, University of Pittsburgh, Pittsburgh, Pa. 15213*

FA3.8 **Directions for Health System Reform,** *KAREN M. EISENSTADT, The Rand Corporation, 1700 Main Street, Santa Monica, Calif. 90406.*

FA3.9 **Identifying the Unidentifiable—The Separation of Test and Assembly Errors within a Repair Facility,** *LEONARD ZACKS, McKinsey and Co., Inc., 245 Park Avenue, New York, New York 10017.*

FA3.10 **Regional Requirements for Hospital Services for Heart Disease Patients,** *ROBERT M. GURFIELD, California Center for Health Services Research, School of Public Health, University of California, Los Angeles, Calif. 90024.*

Abstracts: B-230

FRIDAY AM, October 29 **Conference Room 10**

Session: FA4 9:00-12:00
Educational Sciences Session—Educational Planning in the 70's

Chairman: A M. MOOD
Director, Public Policy Research Org., University of Calif., Irvine, California 92664

FA4.1 **Bases for Design of an Information System: The Affinity and Utility to the Educational Planning Process,** *A.G. HOLZMAN, School of Engineering, University of Pittsburgh, Pittsburgh, Pa. 15213.*

FA4.2 **A Monte Carlo Technique for Sizing the Substitute Teacher Pool,** *JAMES BRUNO, Dept of Education, UCLA, Los Angeles, Calif. 90024.*

FA4.3 **Development and Validation of a Micro Level Forecasting Model for Student Enrollment,** *ISMAIL B. TURKSEN and ERROL D. PORTER, Dept. of Industrial Engineering, University of Toronto, Canada.*

FA4.4 **A Control Theory Approach to Small College Administrative Decisions,** *W. GARY WAGNER and GEORGE B. WEATHERSBY, Dept. of Economics, University of California, Berkeley 94720.*

FA4.5 **On the Use of Large-Scale Simulation Models for University Planning,** *DAVID S.P. HOPKINS, Department of Economics, Stanford University.*

FA4.6 **A Model for Analyzing Decision Making of Investment to Education,** *Y. COMAY and A. MELNIK, Technion, Israel Institute of Technology, Haifa, Israel, and M.A. POLLATSCHEK, Div. of Compensatory Ed., Stanford University, Stanford, California 94305.*

FA4.7 **Acceptable-Optimality Analysis of Qualitative and Quantitative Techniques in Education,** *ASHOK DAVE, Southwest Regional Laboratory for Educational Research and Development, 11300 La Cienega Blvd., Inglewood, California 90304.*

FA4.8 **Models for School District Reorganization,** *DANIEL B. DAVIS, U.S. Office of Education, Div. of Compensatory Education, Dept. H.E.W., Washington, D.C 20202.*

FA4.9 **Measuring Efficiency in Public Schools,** *RICHARD C. CARLSON and HENRY LEVIN, Dept. of Economics, Stanford University, Stanford, California 94305.*

FA4.10 **Relationships Between Manpower Planning and Educational Planning,** *DONALD J. CLOUGH, Department of Management Sciences, University of Waterloo, Ontario, Canada.*

Abstracts: B-231

FRIDAY AM, October 29 **Pacific**

Session: FA5 9:00-12:00
Military Applications Session—Panel Discussion on Group Judgment Technology including Delphi

Chairman: NORMAN C. DALKEY
The Rand Corporation, 1700 Main Street,
Santa Monica, California 90406

Panelists. Dr. NORMAN C. DALKEY (Rand Corporation), Dr. JOHN C. CHAMBERS, Director of Operations Research, Corning Glass Works, Corning, N.Y., 14830; J. KENNETH CRAVER, Manager of Technological Forecasting, Monsanto Co., St. Louis, Missouri, other panelists to be announced.

This panel will present examples of the use of Delphi techniques in organizational decision-making and will discuss the advantages and shortcomings of the approach. Among the considerations to be covered are: (1) effectiveness of the techniques in resolving value conflicts within planning teams, (2) role of the study manager in assuring success of the Delphi process, (3) cross-impact analysis as a corporate planning tool, and (4) effectiveness of group judgment techniques in identifying and rating organizational objectives.

FRIDAY AM, October 29 **Balboa**

Session: FA6 9:00-12:00
Health Applications Session—Application of OR Techniques to Medical Decisions

Chairman: DAVID H. GUSTAFSON
College of Engineering, The University of Wisconsin, Madison, Wisc. 53706

FA6.1 **A Comparison of Three Computer Aided Diagnostic Systems,** *DAVID H GUSTAFSON, JOHN J. KESTLY, JOHN H. GREIST, and NORMAN N. JENSEN, University of Wisconsin, Madison, Wisc. 53706.*

FA6.2 **Measures of Effectiveness for Medical Decisions,** *HARVEY WOLFE, School of Engineering, University of Pittsburgh, Pittsburgh, Pa. 19130.*

FA6.3 **Automating Judgmental Decision Making in Medicine,** *G ANTHONY GORRY, Sloan School of Management, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139.*

FA6.4 **Testing A Model for Predicting Physicians' Evaluations of Health Status,** *DON C. HOLLOWAY, School of Public Health, University of California, Berkeley, Calif. 94720.*

FA6.5 **To Grant or Not to Grant: A Decision Making Process For Funding Health Services Research,** *JOHN R. HALL, SR., National Center for Health Services Research and Development, DHEW, Room 15-19, Parklawn Building, 5600 Fishers Lane, Rockville, Maryland 20852.*

Abstracts: B-234

FRIDAY PM, October 29 **Magnolia C**

Session: FP1 2:00-5:00
Problems of Major Systems—The Resource Allocation Decision, A Panel Discussion

Chairman: ARNOLD H. PACKER
Office of Management and Budget, Executive Office of the President, Washington, D.C. 20503

Panelists: STUART ALTMAN, Urban Institute, Washington, D.C.; ALFRED BLUMSTEIN, Carnegie-Mellon University, Pittsburgh, Pa.; JAMES LYDAY, University of Minnesota, Minneapolis, Minnesota, C.G. NUCKOLS, Department of Defense, Washington, D.C.; FRANK C. RIPLEY, Council of Economic Advisers, Washington, D.C.; RALPH SCHOFER, National Bureau of Standards, Washington, D.C.; and DAVID STOLLER, California State College, Fullerton, California.

This session will explore the feasibility of developing a rational process for allocating total U.S. economic resources among the primary functions of our society. Seven expert panelists will each represent a specific function. Each will present arguments for increasing the share of GNP devoted to his function based upon projections contained in the Budget of the U.S. Government for Fiscal 1972. All seven functions will be examined in terms of opportunity costs. The hypothesis will be that if interfunctional tradeoffs and relationships are considered, then the allocation of total economic resources can reflect national priorities.

FRIDAY PM, October 29 **Magnolia B**

Session: FP2 2:00-5:00
Management of Operations Research, A Panel Discussion

Chairman: GERALD LIEBERMAN
Department of Operations Research, Stanford University, Stanford, California 94305

Panelists. DUANE S. DUNLAP, Aeronautical Systems Division, Wright-Patterson Air Force Base, Ohio; WARREN R. KETLER, Decision Studies Group, Palo Alto, Calif.; LAWRENCE J. LOW, Stanford Research Institute, Menlo Park, Calif.; ALAN H. NOLL, McDonnell Douglas Corp., Long Beach, Calif.; and EDWARD S. QUADE, The Rand Corporation, Santa Monica, Calif. (Note: All are active managers of operations research activities.)

The purpose of the panel is to explore the ill-defined criteria for evaluation of management in Operations Research itself. Thus, the focus of the panel will be on such questions as:

1. What level of resources should be allocated to a particular study? How do we determine when we are overstudying a problem?
2. What criteria do we use for personnel assignment to a program? Should we try for the traditional inter-disciplinary approach of Operations Research? How do we evaluate individual performance?
3. How do we motivate the Operations Research worker toward creative output? How do we protect against biased and scientifically unsound studies? Do we want to protect against these?
4. Are Operations Research groups in the decision-loop or merely window dressing?

FRIDAY PM, October 29 **Balboa**

Session: FP3 2:00-5:00
General Session II—Contributed Papers

Chairman: JOHN P. MAYBERRY
Department of Mathematics, Brock University, St. Catharines, Ontario, Canada

Co-Chairman: MILTON KAMINS
The Rand Corporation, 1700 Main Street, Santa Monica, Calif. 90406

FP3.1 **Mid-Air Collisions in Future Air Traffic Environments,** *KENNETH E. WILLIS, Lambda Corporation, 1501 Wilson Blvd., Arlington, Va. 22209.*

FP3.2 **Airline Fleet Planning Model,** *J.W. STROUP and D.P. SHUBE, Advanced Transportation Concepts, Douglas Aircraft Co., 3855 Lakewood Blvd., Long Beach, Calif. 90801.*

FP3.3 **A Model for Comparing Driver Improvement Programs,** *JOSEPH FERREIRA, JR., Operations Research Center, Massachusetts Institute of Technology, Cambridge, Mass 02139.*

FP3.4 **The Fire Engine Relocation Problem: Formulation and Algorithm,** *WARREN E. WALKER, New York City-Rand Institute, 545 Madison Avenue, New York, New York 10022; and PETER J. KOLESAR, University of Montreal, Montreal, Que.*

FP3.5 **Optimal Resource Allocation in Family Planning Services Delivery,** *WARREN H. HAUSMAN and PHILIPPE A. NAERT, Sloan School of Management, Massachusetts Institute of Technology, Cambridge, Mass. 02139.*

FP3.6 **Some Decision Making Problems in the Planning of R&D,** *O. LARITCHEV, Institute of Management Problems, USSR Academy of Sciences, Profsoyuznaya 81, Moscow B-485, USSR.*

FP3.7 **Some Effects of Food Products Packaging on Solid Waste Disposal Systems,** *RONALD A. NELSON, Nelson Enterprises, P.O. Box 643, Rockville, Md. 20851.*

FP3.8 **The Cost-Benefits of Econometric Studies of Marketing Systems,** *P.C. BURGER, Northwestern University Graduate School of Management, Evanston, Ill. 60201; and R.L. SCHULTZ, University of Pittsburgh, Pittsburgh, Pa. 19130.*

FP3.9 **An Optimum Student Flow Model for Large Scale Higher Educational Systems,** *DAVID A. SANDELL, Dept. of Mathematics, U.S. Coast Guard Academy, New London, Conn. 06320; and WILLIAM A. WALLACE, Director, Urban-Environmental Studies, Rensselaer Polytechnic Institute, Troy, New York 12181.*

FP3.10 **A New Approach For Solving Optimization Problems,** *V.K. CHICHINADZE, N.I. JIBLADZE, and R.G. VACHNADZE, Institute of Control Systems, Academy of Sciences of the Georgian S.S.R., 32 Peking Street, Tbilisi, U.S.S.R.*

Abstracts: B-234

FRIDAY PM, October 29 **Conference Room 10**

Session: FP4 2:00-5:00
Joint Session: Cost Effectiveness and Transportation Sciences

Chairman: WILBERT E. CANTEY
Federal Rail Administration, Department of Transportation, 400 7th Street, S.W., Washington, D.C. 20005.
Co-Chairman: DONALD G. CAPELLE
Alan M. Voorhees and Associates, 1100 Glendon Ave. Los Angeles, Calif. 90024

FP4.1 **Multi-Modal Transportation Model as a Tool for Regional Planning,** *MICHAEL JAY ROBERTS, The Mitre Corporation, McLean, Va. 22101.*

FP4.2 **A Personal Epilogue on the Northeast Corridor Transportation Project: A Pyrrhic Lesson for the Profession,** *JOHN L. DONALDSON, Technical Analysis Division, National Bureau of Standards, Washington, D.C. 20234.*

FP4.3 **The Usefulness of Alternative Techniques for Analyzing Transportation Issues,** *MELVYN CHESLOW, Office of the Assistant Secretary for Policy and International Affairs, U.S. Department of Transportation 20005.*

FP4.4 **Cost Effectiveness Analysis of Incremental Railroad Improvements,** *STEVEN DITMEYER, Office of High Speed Ground Transportation, U.S. Department of Transportation; and LINDA WILSON, Federal Railroad Administration, U.S. Department of Transportation 20005.*

Abstracts: B-236

FRIDAY PM, October 29 **Conference Room 6**

Session: FP5 2:00-5:00
Urban Sciences Session—Current Applications of OR to Urban Service Systems

Chairman: ALBERT M. BOTTOMS
P.O Box 432, Monument Beach, Massachusetts 02553
Co-Chairman: GUSTAVE J. RATH
Northwestern University, Evanston, Illinois 60202

FP5.1 **Decision-Making: The Target of Systems Science in Social Programs,** *ARTHUR SPINDLER, Department of Health, Education and Welfare, Social and Rehabilitation Service, Washington, D.C. 20201.*

FP5.2 **Urban System Decision-Making with Multiple Consequences,** *LOUIS SLADE, JOSEPH SCHOFER and MARTIN WACHS, Northwestern University, Evanston, Illinois 60201.*

FP5.3 **Resource Allocation Models Applied to Fire Departments,** *ERNST NILSSON, DONALD COLVER and RICHARD KU, National Bureau of Standards, Washington, D.C. 20234.*

FP5.4 **Operations Research and Urban Education,** *YING CHUANG, Center for Urban Education, 105 Madison Avenue, New York City, New York 10016.*

FP5.5 **Methods for Allocating Urban Emergency Units,** *JAN M. CHAIKEN, New York City-Rand Institute, 545 Madison Avenue, New York, New York 10022; and RICHARD C. LARSON, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139.*

Abstracts: B-237

Formal presentations will be followed by a discussion with audience participation emphasizing applications of urban sciences and pitfalls therein. Moderator for the discussion will be Mr. BOTTOMS.

FRIDAY PM, October 29 **Pacific**

Session: FP6 2:00-5:00
Health Applications Session—Application of OR Techniques to Large Scale Medical Planning

Chairman: JERRY L. SANDERS
Department of Industrial Engineering, University of Arizona, Tucson, Arizona 85721.
Co-Chairman: DON TRANTOW
Georgia Regional Medical Programs, 938 Peachtree Street, N.E., Atlanta, Georgia 30309

FP6.1 **Operations Research and Systems Engineering: Application in Comprehensive Health Planning,** *RICHARD F. JACOBSEN, Comprehensive Health Planning, San Diego and Imperial Counties, Municipal Bldg., San Diego, Calif. 92103.*

FP6.2 **The Use of OR Techniques in Regional Medical Programs,** *DON TRANTOW, Georgia Regional Medical Programs, 938 Peachtree Street, Atlanta, Georgia 30309.*

FP6.3 **Systems Engineering Applications in the Kaiser-Permanente Program,** *MORRIS F. COLLEN, Kaiser Foundation Research Institute and Permanente Medical Group, Oakland, California 94612.*

FP6.4 **Operations Research and Planning in the Indian Health Service,** *E.S. RABEAU, Indian Health Service, U.S. Public Health Service.*

Abstracts: B-238

Formal papers will be followed by a round table discussion with audience participation on "Future Areas of Application for Operations Research in the Health Fields"; panel moderator: JOHN KRAWLESKI, Dept. of Preventive Medicine, Denver Medical Center, Denver, Colorado.

FRIDAY PM, October 29 **Press Room**

Session: FP7 2:00-5:00
Special Student Session

Chairman· BENNET LIENTZ
Dept. of Industrial and Systems Eng., University of So. Calif., Los Angeles, California 90007

FP7.1 **Allocation of Resources for Barrier Patrol Missions,** *EDWARD R. JAHN, Dept. of Industrial and Systems Eng., University of Southern California, Los Angeles, California 90007.*
Referee. Dr. PERRI L. STINSON, California State College, Long Beach, Calif. 90801.

FP7.2 **The Evolution of Game Theory,** *JOSEPH JONES, California State College, Long Beach, California 90801.*
Referee: Mr.JOEL LUBIN, Dept. of Industrial and Systems Eng., University of Southern California 90007.

FP7.3 **An Application of Linear Programming to Optimal Product/Market Mixture for Olson Brothers,** *DONALD REIFER, Dept. of Industrial & Systems Engineering, University of Southern California, Los Angeles, California 90007.*
Referee: Dr. PERRI STINSON, California State College, Long Beach, California 90801.

FP7.4 **A System for Controlling Major Milestone Accomplishment in Project Planning,** *JOHN R. SINGRIN, California State College, Long Beach, California 90801.*
Referee· Dr BENNET LIENTZ, University of Southern California.

FP7.5 **Simulation of Decision Making in a Business Game,** *WILLIAM FARRELL, University of California at Los Angeles 90024.*
Referee: Mr. JOEL LUBIN, University of Southern California.

Abstracts: B-239

PROGRAM FOR SIMULTANEOUS SESSIONS

THURSDAY AM, October 28 **Embassy Room**

Session: SS1A 9:00-11:00
Abstracts. B-240

Session: SS1B 11:00- 1:00
Abstracts. B-249

Paper Fair Session 1

Chairman STEPAN KARAMARDIAN
Graduate School of Administration, University of California, Irvine, Irvine, California 92664

Session 1A features urban and educational science applications. Session 1B features social science and military applications of operations research.

SS1A.1 **Long Range Student Scheduling Using Pert,** *THOMAS B. BAIRD, WILLIAM ARBOGAST, Computer Science Department, University of Missouri-Rolla, Rolla, Missouri 65401.*

SS1A.2 **Some Manpower Planning Models Based on Levels of Educational Attainment,** *WARREN L. BALINSKY, School of Management, State University of New York at Buffalo, Crosby Hall, Buffalo, New York 14214.*

SS1A.3 **The Creation of New Agricultural Communities to Stem the Flow of Individuals to Urban Areas,** *JERRY BANKS, and JOHN C. DeVITTO, Georgia Insti-*

tute of Technology, School of Industrial and Systems Engineering, Atlanta, Georgia 30332.

SS1A.4 **The Study of the Traffic Intersection through Simulation,** *J. WESLEY BARNES, and ROBERT M. CRISP, JR., Bell Laboratories, 2525 Shadeland Avenue, Indianapolis, Indiana 46206.*

SS1A.5 **Development and Growth of Urban Areas Caused by New Transportation Systems,** *HENRI L. BEENHAKKER, Department of Industrial and Management Engineering, 1202 Engineering Building, The University of Iowa, Iowa City, Iowa 52240.*

SS1A.6 **A Computerized Model for Analyzing School District Financial Problems,** *A.J. BENJAMIN, R. JOHN PREVOST, and T.E. HAWKINS, Southwest Research Institute, Operations Research Section, Department of Social and Management Sciences, P.O. Drawer 28510, San Antonio, Texas 78228.*

SS1A.7 **A Pupil Performance Measure for Criterion Referenced Instructional Programs,** *RONALD BESEL, Southwest Regional Laboratory for Educational Research and Development, 11300 La Cienega Boulevard, Inglewood, California 90304.*

SS1A.8 **An Urban Systems Study for Melbourne,** *JOHN F. BROTCHIE, RON SHARPE, A. RAY TOAKLEY, and JOHN W. DICKEY, Systems Research Section, Division of Building Research, Commonwealth Scientific and Industrial Research Organization, Highett, Victoria, Australia.*

SS1A.9 **Measuring Urban Performance,** *ALBERT BROWN and RONALD F. KIRBY, PRC Systems Sciences Company, 7600 Old Springhouse Road, McLean, Virginia 22101.*

SS1A.10 **Crime Prediction Modeling,** *ROBERT G. CHAMBERLAIN, Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, California 91103.*

SS1A.11 **On An Optimal Allocation of Pupils with A Public School System Operating Under A Racial Balance Constraint,** *WILLIAM E. CULLISON, Federal Reserve Bank of Richmond, Eighth & Franklin Street, Richmond, Virginia 23213.*

SS1A.12 **Analysis of Housing Decay,** *ANDREW F. DAUGHETY, Department of Operations Research, Case Western Reserve University, Cleveland, Ohio 44106.*

SS1A.13 **Actors, Factors and Urban Performance Indicators,** *JOHN W. DICKEY and ROBERT C. STUART, Division of Environmental and Industrial Engineering, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061.*

SS1A.14 **The Social Feasibility of Computer-Aided Instruction,** *EDWIN DUPNICK, University of Arizona, Tucson, Arizona 85721.*

SS1A.15 **Teaching Urban Systems—A Large Scale Project Approach,** *PAUL GRAY, Stanford University, School of Engineering Department of Industrial Engineering, Stanford, California 94305.*

SS1A.16 **School Vandalism: A National Dilemma,** *BERNARD GREENBERG, Systems Analysis Department, Stanford Research Institute, Menlo Park, California 94025.*

SS1A.17 **Systems Analysis of Effectiveness of Techniques in Prevention of Chicago Transit Authority Bus Robberies,** *LONNIE E. HAEFNER, University of Maryland, Department of Civil Engineering, College Park, Maryland 20742.*

SS1A.18 **Experiments With An Interactive Search Procedure for Changing Transportation to Guide Urban Growth,** *R.A. HALL and J.W. DICKEY, Civil Engineering Department, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061.*

SS1A.19 **Optimal Selection of University Course Offerings,** *JAMES A. HEINEN, EDWIN C. FOUDRIAT, Systems Group, Department of Electrical Engineering, Marquette University, Milwaukee, Wisconsin 53233.*

SS1A.20 **Partitioning of Police Districts Into Optimal Patrol Beats Using A Political Districting Algorithm: Model Design and Validation,** *NELSON B. HELLER, ROBERT E. MARKLAND, JAMES A. BROCKELMEYER, Staff Members, Board of Police Commissioners, St. Louis Metropolitan Police Department, St. Louis, Missouri 63103.*

SS1A.21 **An Intercity Comparison of the Cost of Police Services,** *RICHARD B. HOFFMAN, Assistant Professor of Operations Analysis, School of Management, State University of New York at Buffalo, Buffalo, New York 14214*

SS1A.22 **The Servomechanistic Aspects of Congestion Problem,** *PHILIP HUANG, North Electric, P.O. Box No. 688, Galion, Ohio 44833.*

SS1A.23 **A Comprehensive Elementary and Secondary Education System (CEASES),** *WALTER LEE HUGHEY, Atlanta Public Schools, Instructional Services Center, 2930 Forest Hill Drive, S.W., Atlanta, Georgia 30315.*

SS1A.24 **Experience In Working Urban Problems: Some Observations,** *J.P. IGNIZIO, R.M. WYSKIDA, R.E. SHANNON, The University of Alabama in Huntsville, Department of Industrial and Systems Engineering, P.O. Box 1247, Huntsville, Alabama 35807.*

SS1A.25 **Uncertainties and Electricity Planning,** *PRAFULLA JOGLEKAR, Management and Behavioral Science Center–University of Pennsylvania, Philadelphia, Pennsylvania 19104.*

SS1A.26 **Problems in Urban Transportation Planning,** *THOMAS M JOHNSTON, Raytheon Company, Missile Systems Division, Hartwell Road, Bedford, Massachusetts 01730.*

SS1A.27 **Humanistic Technology: A Contradiction in Terms?** *DAVID W. KEAN, Techno/Culture Associates, 19687 Gray Avenue, Sunnyvale, California 94086.*

SS1A.28 **A Survey of Approaches to the Facility Location Problem,** *BASHEER M. KHUMAWALA and D. CLAY WHYBARK, Graduate School of Business, University of North Carolina, Chapel Hill, North Carolina 27514.*

SS1A.29 **The Zodiac Cipher: A Triple Overlay,** *BARTON S. LOCKWOOD, Systems Analysis, Mail Number 1043, Martin Marietta Corporation, P.O. Box 179, Denver, Colorado 80201.*

SS1A.30 **Cost Effectiveness Evaluation of Freeway Design Alternatives,** *ADOLF D. MAY, Department of Civil Engineering, Room 114, McLaughlin Hall, University of California 94720.*

SS1A.31 **The Anticipation of Requirements for Police Assistance,** *ELDON S. MILLER, Center of Community and Metropolitan Studies, University of Missouri-St. Louis, St. Louis, Missouri 63121.*

SS1A.32 **Models For Fire Department Resource Allocation,** *PHILLIP S. MITCHELL, Associate Professor, California State College, 800 N. State College Boulevard, Fullerton, California 92631.*

SS1A.33 **A Resource Allocation Model for The Educational Sector,** *JOHN M. MULVEY, TRW Systems Group 76/8122, One Space Park, Redondo Beach, California 90278.*

SS1A.34 **Prototypical Forms Of Dialogue For Metropolitan Planning,** *CHRIS McDONALD and DAVID E. BOYCE, Regional Science Department, Wharton School of Finance and Commerce, University of Pennsylvania, Philadelphia, Pennsylvania 19104.*

SS1A.35 **Use of an Incident Seriousness Index in Deployment of Police Patrol Manpower,** *J. THOMAS McEWEN and NELSON HELLER, Board of Police Commissioners, St. Louis Police Department, 1200 Clark Avenue, St. Louis, Missouri 63103.*

SS1A.36 **Housing and Racial Transition: The Process and Policy Implications,** *DONALD PHARES, and ELDON MILLER, Center of Community and Metropolitan Studies, University of Missouri, St. Louis, Missouri 63121.*

SS1A.37 **Public and Community Relations as an Answer to the Social Problems of Urban Fire Departments,** *ALBERT PINES, Technical Analysis Division, National Bureau of Standards, Washington, D.C. 20234.*

SS1A.38 **A Branch-Select Algorithm for Capital-Budgeting Problem with Interrelated Projects,** *P RAMALINGAM, Industrial Engineering Department, California State Polytechnic College, Pomona, California 91768.*

SS1A.39 **The Motor Vehicle Operating Cost Function,** *SAMUEL W. ROSS, Transportation Planning, Department of Traffic, City of Los Angeles, 1200 City Hall, Los Angeles, California 90012.*

SS1A.40 **Restructuring the Inner City Marketplace by Simulation,** *DONALD E. SEXTON, JR., Assistant Professor, Graduate School of Business, Columbia University, New York 10027.*

SS1A.41 **Class and Subject Scheduling in A Further Education College,** *P.R SHELTON, North Devon Technical College, Barnstable, Devon, England.*

SS1A.42 **A Needs-Oriented Systems Perspective of the City,** *J. TALAVAGE and W. CRICHTON, Georgia Institute of Technology, Atlanta, Georgia 30332.*

SS1A.43 **A Method of Establishing Traffic Signal Warrant for Heavy Traffic Volume Occurring During A Short Time Period,** *JASON C. YU and VINOD CHACHRA, Civil Engineering Department, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061.*

SS1A.44 **A Systems Analysis of Police Vehicle Ownership,** *HERBERT G. LUDWIG and FRANCIS E. PLONKA, Wayne State University, Detroit, Michigan 48202.*

SS1A.45 **A Functional Description Of The Police Patrol Vehicle,** *JAMES E. BAILEY and HERBERT G. LUDWIG, Wayne State University, Detroit, Michigan 48202.*

SS1B.1 **Simulation of City Politics,** *FRANK L. ADELMAN and IRMA ADELMAN, Center for Advanced Study in the Behavioral Sciences, 202 Junipero Serra Boulevard, Stanford, California 94305.*

SS1B.2 **A Proposed Methodology for Correlating Cultural Environments and Potential Management Innovation,** *LESLIE P. ANDERSON, and FREDERICK C. WESTON, University of Colorado, Denver, Colorado 80220; and VERGIL V. MILLER, University of California, Irvine, California 92664.*

SS1B.3 **Geographic Market Potential & Performance: An Evaluation Technique,** *M.N. BARTAKKE and W.A. HALL, Sperry Rand Corporation, UNIVAC Division, Blue Bell, Pennsylvania 19422.*

SS1B.4 **Measurement of Individuals' Priorities for National Goals,** *JAMES R. BETTMAN, Graduate School of Business, University of California, Los Angeles, California 90024.*

SS1B.5 **Evaluation of Innovative Programs in Urban Education,** *FRANCIS M. BETTS, III, University of Pennsylvania, Philadelphia, Pennsylvania 19104.*

SS1B.6 **Ethics and Operations Research,** *DONALD B. BROUT, ITT Continental Baking Company, Rye, New York 10580.*

SS1B.7 **Managerial Effectiveness in Systems Operations,** *ROBERT A. BROWN, The University of Alabama, Huntsville, Alabama 35907.*

SS1B.8 **Programming Approach to the Criminal Justice System,** *R.G. CASSIDY, Carnegie-Mellon University, Pittsburgh, Pennsylvania 15213.*

SS1B.9 **Cybernetics and Educational Evaluation,** *YING C. CHUANG, Center for Urban Education, 105 Madison Avenue, New York, New York 10016.*

SS1B.10 **An Effectiveness Evaluation Model for Community-Based Social Services Delivery Systems,** *ROBERT M. CLINKSCALE and MARILYN P. RYMER, Booz, Allen Public Administration Services, Inc., 1025 Connecticut Avenue, N.W., Washington, D.C. 20036.*

SS1B.11 **A Systems Approach to Societal Problems,** *DAVID A. CURRY, Stanford Research Institute, Menlo Park, California 94025.*

SS1B.12 **Determination of the Defensive Versus Offensive Payloads of Strategic Bomber Aircraft to Obtain Maximum Target Destruction,** *MAJOR JOHN R. CURRY, JR., USAF, DCS Comptroller, HQ Air Force Logistics Command, Wright-Patterson AFB, Ohio 45433.*

SS1B.13 **The Application of Operations Research to Social Welfare Planning at the Jewish Community Federation of Cleveland,** *BURTON V. DEAN, ROBERT REICH, ARNOLD REISMAN, ALLAN L. SERVICE, ARTHUR BLUM, RAYMOND KOLESKI, Case Western Reserve University, Cleveland, Ohio 44106; MIRIAM JAFFE, HOWARD RIEGER, RICHARD RONIS, JUDAH RUBINSTEIN, The Jewish Community Federation of Cleveland; and SAMUEL J. MANTEL, JR., University of Cincinnati, Cincinnati, Ohio 45221.*

SS1B.14 **Systems Analysis, Operations Research, and Social Systems,** *S.J. DEITCHMAN, Institute for Defense Analyses, 400 Army-Navy Drive, Arlington, Virginia 22202.*

SS1B.15 **The Social Security (HEW) Evaluation and Measurement System,** *JACOB DEUTCH, SYLVAN HACK, and SAUL D. HEARN, University of Baltimore, Baltimore, Maryland 21201.*

SS1B.16 **Sociotechnological Forecasting,** *J.N. FOX, The University of Texas, Arlington, Texas 76010.*

SS1B.17 **Day Care Centers--An Analysis Overview,** *DENNIS M. GALVIN, North American Rockwell Corporation, 12214 Lakewood Boulevard, Downey, California 90241.*

SS1B.18 **An Application of the Systems Approach to Educational Planning,** *P.C. GEORGALLIS and P.H. NISBET, Tetra Tech, Inc., 1911 Fort Meyer Drive, Arlington, Virginia 22209.*

SS1B.19 **Sharing Responsibility for the Ethical Use of Technology,** *RICHARD D. GOODFRIEND, 14709 Lake Terrace, Rockville, Maryland 22101.*

SS1B.20 **New Horizons in Application of Systems Sciences to Management,** *RICHARD M. GREENE, JR., R.M. Greene & Associates, 1044 Concord Street, Costa Mesa, California 92626.*

SS1B.21 **Evaluation of Transportation Plans: A Survey of Methodologies,** *GEORGE D. HALUSHYNSKY, Vitro Laboratories, 14000 Georgia Avenue, Silver Spring, Maryland 20910.*

SS1B.22 **A Means of Quantitatively Assessing the Effect of Lawyer Behavior on Court Management Performance,** *ROBERT HOWARD, U.S. Army Combat Development Command, Institute of Special Studies, Ft. Belvoir, Virginia 22060.*

SS1B.23 **Micro Analysis in Higher Education Decision Making,** *ROBERT C. JUDD, University of Toledo, Toledo, Ohio 43606.*

SS1B.24 **Modeling a Responsive Message Exploitation System,** *LT. JOHN C. MAYSON, III, and PATRICK B. SAMPEY, U.S. Strike Command, Macdill AFB, Florida 33608.*

SS1B.25 **Dormant System Maintenance Value Analysis,** *CHARLES C. KELBER, McDonnell Douglas Astronautics Company--West, 5301 Bolsa Ave., Huntington Beach, California 92647.*

SS1B.26 **Programmed Goals--Achievement Matrices for Selecting Alternative Public Investment Plans,** *THEODORE KLASTORIN and TIMOTHY RUEFLI, University of Texas, Austin, Texas 78702.*

SS1B.27 **Cost--Effectiveness Evaluation of the Volunteer Army Field Experiment,** *WILLIAM A LINDSAY, Research Analysis Corporation, McLean, Virginia 22101.*

SS1B.28 **Analytic Models of Criminal Court Operations,** *NORMAN R. LYONS, Cornell University, Ithaca, New York 14850.*

SS1B.29 **Ex Ante Hardness of Data Analysis: An Approach to the "Soft Data" Creditability Problem,** *D.V. MATHUSZ, Department of the Army, U.S. Army Aviation Systems Command, P.O. Box 209, St. Louis, Missouri 63166.*

SS1B.30 **A Mathematical Programming Model of Educational Planning with Quantitative and Qualitative Sub-Objectives: A Case Study of Korea,** *LEO Y. MIN, The Catholic University of America, Washington, D.C. 20017.*

SS1B.31 **The Relationship between Formal Procedures for Pursuing OR/MS Activities and OR/MS Group Success,** *RODNEY D. NEAL, University of Arkansas 72701; and MICHAEL RADNOR, Northwestern University, Evanston, Illinois 60201*

SS1B.32 **Effective Utilization of OR/MS Consultants,** *FREDERIC K. ROSEN, Jos. Schlitz Brewing Company, 235 West Galena Street, Milwaukee, Wisconsin 53212.*

SS1B.33 **On the Business of Science,** *FRANCISCO SAGASTI and PRAFULLA JOGLEKAR, Management and Behavioral Science Center, University of Pennsylvania, Philadelphia, Pennsylvania 19104.*

SS1B.34 **Personal Accountability and Ethical Use of Technology,** *ROLAND SCHINZINGER, School of Engineering, University of California, Irvine, California 92664.*

SS1B.35 **Professional Decision Making,** *JEROME H.N. SELMAN, U.S. Army Munitions Command, Dover, and Stevens Institute of Technology, Hoboken, New Jersey 07030.*

SS1B.36 **How Much is Your Life Worth?** *JEROME H.N. SELMAN, U.S. Army Munition Command, Dover, N.J. 07030; and VICTOR SELMAN, Computer Sciences Corporation, 6565 Arlington Boulevard, Falls Church, Virginia 22046.*

SS1B.37 **New Implementation Models of "O.R.",** *A. FOUAD SHERIF, Inter-Regional Advisor to the Public Adm. Div., United Nations Headquarters and FAREED R. ELNAGGER, Division of Business and Management, New York Inst. of Technology, Wheatley Road, Old Westbury, Long Island, New York 11568.*

SS1B.38 **Commodity Allocation: A Voting Model Approach,** *WILLIAM R. SHERRARD and ROBERT L. BUTLER, San Diego State College, San Diego, California 92115*

SS1B.39 **Application of a Flexible System to Retrieve, Manipulate and Display Information from a Stable Questionnaire-Oriented Data Base to Social Science Research,** *CHRISTOPHER R. SPRAGUE and DAVID NESS, M.I.T., Alfred P. Sloan School of Management, 50 Memorial Drive, Cambridge, Massachusetts 02139.*

SS1B.40 **The Dilemma Between Planning and Freedom of Action,** *JOHN P. VAN GIGCH, ABBASS BARZGAR, and R. DURGIN, School of Business Administration, Sacramento State College, Sacramento, California 95819.*

SS1B.41 **The Assumptions of Systems Analysis,** *ERNEST H. WEINWURM, San Fernando Valley State College, School of Business Administration and Economics, Northridge, California 91324.*

SS1B.42 **Transportation and New Communities,** *MARCUS S. WEISS, Boston University, 836 Beacon Street, Boston, Massachusetts 02215.*

THURSDAY PM, OCTOBER 28 Embassy Room

Session: SS2A 1:00–3:00
Abstracts: B-259

Session: SS2B 3:00–5:00
Abstracts: B-268

Paper Fair Session 2

Chairman: CURTIS EAVES
Department of Operations Research, Stanford University, Stanford, California 94305

Session 2A features advances in methodology. Session 2B features health applications.

SS2A.1 **An Analysis of Key-Stroke Errors Undetected by the Zero-Sum Check,** *STEPHEN G ALLEN, Sacramento State College, 6000 Jay Street, Sacramento, California 95819.*

SS2A.2 **A Bus-Traveler Algorithm for Single Destinations,** *DEAN N. ARDEN, HELMAN I. STERN, Rensselaer Polytechnic Institute, Troy, New York 12181; and THOMAS A. WILLIAMS, University of Cincinnati, Cincinnati, Ohio 45221.*

SS2A.3 **Autoregressive Moving Average Models for Forecasting Telephone Movement,** *SUDHIR K. ARORA and AMRIT L. GOEL, Syracuse University, Syracuse, New York 13210.*

SS2A.4 **Linear Programming as a Budgeting Tool,** *JOSEPH H. AUGUSTA and NORMA J. HIBBS, The Center for Naval Analyses, 1401 Wilson Boulevard, Arlington, Virginia 22305.*

SS2A.5 **Parallel Processing and Integer Programming,** *EGON BALAS, Carnegie-Mellon University, Pittsburgh, Pennsylvania 15213.*

SS2A.6 **Optimization of a Multi-National Physical Distribution System,** *M.N. BARTAKKE, J.V. BLOOMQUIST, J.K. KORAH and J.P POPINO, Sperry Rand Corporation, P.O. Box 500, Blue Bell, Pa. 19422.*

SS2A.7 **Measuring Spatial Interactions: Gravity and Some Alternatives,** *MARTIN J. BECKMANN, Brown University, Providence, Rhode Island 02912; and Technische Hochschule Munchen, Germany, and THOMAS F. GOLOB and RICHARD L. GUSTAFSON, General Motors Research Laboratories, Warren, Michigan 48089.*

SS2A.8 **Conversational Computerized Statistical Analysis in Business,** *JOE BULAT, Burroughs Corporation, Burroughs at Second Avenue, Detroit, Michigan 48232.*

SS2A.9 **Consideration of Reliability in a Multi-State System,** *R.M. BURTON, W.W. DAMON, Graduate School of Business Administration, Duke University, Durham, North Carolina 27706.*

SS2A.10 **Relationship Between Optimal Capacity Expansion in Infinite and Finite Horizon Problems,** *ROBERT C. CARLSON, Stanford University, Stanford, California 94305.*

SS2A.11 **Two Stage Programming Under Uncertainty: A Game Theoretic Approach,** *R.G. CASSIDY, School of Urban and Public Affairs, Carnegie-Mellon University, Pittsburgh, Pennsylvania 15213; C.A. FIELD and M.J.L. KIRBY, Dalhousie University, Halifax, Nova Scotia.*

SS2A.12 **Truncated Dynamic Programming and Network Capacity Planning,** *P. DOULLIEZ, Société de Traction et d' Electricité, Brussels, Belgium, and M.R. RAO, University of Rochester, Rochester, New York 14627.*

SS2A.13 **Optimal Markovian Replacement with Inspection Costs,** *HAMILTON EMMONS, Cornell University, Upson Hall, Ithaca, New York 14850; JEAN-MARIE POIMBOEUF, 1 Rue Counil, 77 Chelles, France.*

SS2A.14 **Consistent Preference Functions,** *SHERWOOD C. FREY, JR. and STEPHEN P BRADLEY, Harvard University, Soldiers Field, Boston, Massachusetts 02163.*

SS2A.15 **Alternate Routes Through the Simplex Method,** *HENRY D. FRIEDMAN, University of Santa Clara, Santa Clara, California 95053.*

SS2A.16 **Techniques for Allocating Costs Among Participants in A Regional System,** *RICHARD J GIGLIO, and ROBERT WRIGHTINGTON, University of Massachusetts, Amherst, Massachusetts 01002.*

SS2A.17 **Comparison of General Exponential Smoothing Models for Short-Range Forecasting,** *GENE K. GROFF, Indiana University, Bloomington, Indiana 47401.*

SS2A.18 **Set Covering Problem with Equality Constraints,** *D.K. GUHA, The Port of New York Authority, 111 Eighth Avenue, New York, New York 10011.*

SS2A.19 **Against a Universal Model Methodology,** *JOHN R. HALL, JR., University of Pennsylvania, 4025 Chestnut Street, Philadelphia, Pennsylvania 19104.*

SS2A.20 **Decomposition Model for Regional Educational Planning,** *EDWIN L. HULLANDER, Iowa State University of Science and Technology, Ames, Iowa 50010.*

SS2A.21 **The Application of a Feedforward Control System for Profit Planning and Control,** *AKIRA ISHIKAWA and CHARLES SMITH, Graduate School of Business, The University of Texas at Austin, Austin, Texas 78712.*

SS2A.22 **A Partitioning Technique for Obtaining Solutions to the Modularization Problem,** *PAUL A. JENSEN, and AUGUST J. CAPONECCHI, MAJOR, USAF, Department of Mechanical Engineering, University of Texas, Austin, Texas 78712.*

SS2A.23 **A Dynamic Simulation Approach Solves Problems in Facilities Planning and Adds a New Dimension to Conventional Cost Analysis,** *L.G. KLINGEN, W.B. EVANS, Eastern Airlines, Inc., Miami International Airport, Miami, Florida 33148.*

SS2A.24 **Simulating a Casualty Insurance Operation,** *DUANE C. KNAUER, Nationwide Insurance Co., 246 N. High Street, Columbus, Ohio 43216.*

SS2A.25 **Piecewise Markov Processes in the Theory of Queues,** *A. KUCZURA, Bell Telephone Laboratories, Incorporated, Holmdel, New Jersey 07733.*

SS2A.26 **The Army Pipeline System Study,** *R. STANLEY LA VALLEE, U.S. Postal Service, Research and Engineering Department, 1100 L Street, N.W., Washington, D.C. 20260.*

SS2A.27 **An Uncertainty Principle of Modelling,** *G. ARTHUR MIHRAM, University of Pennsylvania, Philadelphia, Pennsylvania 19104.*

SS2A.28 **A General Analysis of Closed Loop Conveyor Systems,** *E.J. MUTH, and S.D. ROBERTS, University of Florida, Gainesville, Florida 32601.*

SS2A.29 **Evaluating Heuristics for Vehicle Scheduling,** *BRIAN O'NEIL, Purdue University, Lafayette, Indiana 47907.*

SS2A.30 **Decision Analysis of the "Influenced Voter" Problem,** *M. WAYNE PARKER, LARRY G. BROWN, and CARL BUTLER, Mississippi State University, State College, Mississippi 39762.*

SS2A.31 **Single Server Queues with Service Time Dependent on the Waiting Time,** *MORTON J M. POSNER, University of Toronto, Toronto, Canada.*

SS2A.32 **Another Multistage Sequential Decision Algorithm,** *D.F. SANDERSON, Western Washington State College, Bellingham, Washington 98225.*

SS2A.33 **Decision Analysis and Sensitivity,** *RICHARD SHACHTMAN, University of North Carolina, Chapel Hill, North Carolina 27514.*

SS2A.34 **Optimal Reordering Policies for Substitute Items,** *ARVIND A. SHAH, Babson College, Wellesley, Massachusetts 02157.*

SS2A.35 **Stadan and Data Relay Satellite Simulation,** *NORMAN SHUSTERMAN and BARRY KERNE, Operations Research, Inc., 1400 Spring Street, Silver Spring, Maryland 20910.*

SS2A.36 **Multiple-Item Multiple-Source Procurement Policy with Several Warehouses,**

EDWARD A. SIECIENSKI and P.T. LELE, Western Electric Company, P.O. Box 900, Princeton, New Jersey 08540.

SS2A.37 **The m–Traveling Salesman Problem with Ordered Visits,** *HELMAN I. STERN, EDGARDO P. RODRIGUEZ and MERLIN L. UTTER, Rensselaer Polytechnic Institute, Troy, New York 12181.*

SS2A.38 **The Continuous Version of Bellman's Stochastic Gold-Mining Process and Optimal Control,** *JAMES G. TAYLOR, Naval Postgraduate School, Monterey, California 93940.*

SS2A.39 **A New Effect of Probability on Optimal Pricing,** *G. THOMAS, University of Hawaii, Honolulu, Hawaii, and A. WHINSTON, and G. WRIGHT, Purdue University, West Lafayette, Indiana 47907*

SS2A.40 **Applications of the Relationships Between Decision Tree and Simulation Systems Logic,** *ROBERT W.L THOMAS, Wolf Research and Development Corporation, Riverdale, Maryland 20840.*

SS2A.41 **Allocation of Resources,** *C.J. THORNE, Weapons Program Management Department, Naval Missile Center, Point Mugu, California 93042.*

SS2A.42 **Control of A Two-Customer-Class Interactive Multi-Facility Queuing System,** *JAMES M. TIEN, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139.*

SS2A.43 **Decisions Based on Limited Data,** *N.S. TZANNES, University of Oklahoma, Norman, Oklahoma 73069.*

SS2A.44 **Inherent Problems with a Flow Receipt Inventory Model for Intermittent Production Operations,** *Dr FREDERICK C. WESTON, JR., Colorado State University, Fort Collins, Colorado 80521.*

SS2A.45 **A Program Manager's Dilemma or How to Balance Your Budget When you Don't Know What Demand Is,** *DENNIS R YOUNG, The Urban Institute, 2100 M Street, N.W., Washington, D.C. 20037.*

SS2B.1 **Path Analysis: A New Approach to Modelling Health Service Delivery Systems,** *JAMES G. ANDERSON, Purdue University, Lafayette, Indiana 47907*

SS2B.2 **The Use of Decision Theory in Treatment Selection,** *GARY M. ANDREW, School of Business Administration, University of Minnesota, Minneapolis, Minnesota 55455; and WILTON H. BUNCH, Department of Orthopedics, University of Virginia Hospital, Charlottesville, Virginia 22901.*

SS2B.3 **Block and Cyclic Scheduling for Radiologists (Physicians)–Does It Work?** *ROBERT C. BANASIK, Riverside Methodist Hospital, 3535 Olentangy River Road, Columbus, Ohio 43214.*

SS2B.4 **Primary Health Care Delivery System Simulator,** *M.A. BAUM, The MITRE Corporation, McLean, Virginia 22101.*

SS2B.5 **A Car-Following Model Relating Reaction Time and Temporal Headways to Accident Frequency,** *EDWARD A. BRILL, Naval Postgraduate School, Monterey, California 93940.*

SS2B.6 **A Mathematical Programming Approach to Designing an Optimum Health Program Mix,** *MILTON CHEN and J.W. BUSH, University of California at San Diego, Department of Community Medicine, La Jolla, California 92037.*

SS2B.7 **Optimal Short Term Financing Decision Under Uncertainty,** *PETER A. CROSBY, Stanford University, Department of Industrial Engineering, Stanford, California 94305*

SS2B.8 **Role of the Medical Center in the Community,** *DONALD F. CUDDIHEE, SR., Karlsberger and Associates, P.O. Box 125, Princeton Junction, New Jersey 08550*

SS2B.9 **An Analysis of the Logistics of Sterile Medical/Surgical Supply and Material Support for Army Field Hospitals,** *STEPHEN FINEMAN, Arthur D. Little, Inc , Acorn Park, Cambridge, Massachusetts 02140.*

SS2B.10 **The Grisly Analytics of Death, Disability, and Disbursements,** *BRIAN E.*

FORST, Center for Naval Analysis, 1401 Wilson Boulevard, Arlington, Virginia 22209.

SS2B.11 **Branch Office Queue Simulation Model,** *HARVEY FRANK, IBM, 112 East Post Road, White Plains, New York 10601.*

SS2B.12 **Earnings Per Share and APB Opinion #15: A Simulation Model,** *GEORGE M. FRANKFURTER and BERTRAND HORWITZ, College of Business Administration, Syracuse University, Syracuse, New York 13210.*

SS2B.13 **Automated Medical History Data Processing,** *R.C. TEGTMEYER, Medical Systems Department, Martin Marietta Corporation, Denver, Colorado 80201.*

SS2B.14 **Health Disorders of the Urban Poor, Spatial Analysis of the Economics of Health Facility Location,** *PAUL F. GROSS, University of Saskatchewan, Regina, Saskatchewan, Canada.*

SS2B.15 **Operations Research in Hospital Design,** *RALPH H. CONWAY, University of Hawaii, 1960 East-West Road, Honolulu, Hawaii 96822.*

SS2B.16 **A Random Vector Payoff Two-Person Game to Study the Cost-Effectiveness of Service Warranty Policies,** *TIEN-FANG HOU, Bell Telephone Laboratories, Holmdel, New Jersey 07733.*

SS2B.17 **Cybernetic Modeling of Adaptive Systems,** *DANIEL HOWLAND, College of Administrative Science, Ohio State University, 308a Hagerty Hall, 1775 S College Road, Columbus, Ohio 43210.*

SS2B.18 **Body Thermal Comfort and Linear Programming,** *FU-TONG HSU, Wayne State University, Detroit, Michigan 48202.*

SS2B.19 **Developing a Management Information System for a National Health Care Grant Program,** *FRANCIS C. ICHNIOWSKI, Regional Medical Programs Service, Rockville, Maryland 20800.*

SS2B.20 **An Analysis of a Health Care Delivery System,** *ROBERT C. KOHBERGER and JAMES MAHERIS, Rensselaer Polytechnic Institute, Troy, New York 12181.*

SS2B.21 **Estimating Hospital Costs While Controlling Case-Mix Variation,** *LESTER B. LAVE, JUDITH R. LAVE and LESTER P. SILVERMAN, Carnegie-Mellon University, Schenley Park, Pittsburgh, Pennsylvania 15213.*

SS2B.22 **The Iowa Redistricting System,** *JOHN M. LITTSCHWAGER, University of Iowa, Iowa City, Iowa 52240.*

SS2B.23 **An Evaluation of the Use of Some Library Programs in Operations Research,** *JOEL H. LUBIN, University of Southern California, Los Angeles, California 90007.*

SS2B.24 **Medium and Short Term Scheduling of Nursing Staff,** *CHRISTOPH MAIER-ROTHE and HARRY B. WOLFE, Arthur D. Little, Inc., Acorn Park, Cambridge, Massachusetts 02140.*

SS2B.25 **A Study of a Hospital Admissions System,** *L. WILLIAM MILLER, H.M. ALEXANDER, SR., F.F. BARAN, JR. and D.C. CARD, Jet Propulsion Laboratory, Pasadena, California 91103.*

SS2B.26 **Control of Blood Utilization Performance by Hospitals,** *C. CARL PEGELS, ANDREW E. JELMERT, KENNETH E. KENDALL, JOHN P. SEAGLE and EDWARD L. WALLACE, State University of New York at Buffalo, Buffalo, New York 14214.*

SS2B.27 **Sharpe's Diagonal Model: Unknown Parameters and Stochastic Security Index,** *HERBERT E. PHILLIPS, State University of New York at Buffalo, Buffago, N.Y. 14214; GEORGE M. FRANKFURTER, Syracuse University, Syracuse, N.Y. 13210.*

SS2B.28 **Optimal Issuance of Whole Blood From a Hospital Blood Bank,** *WILLIAM P. PIERSKALLA, Northwestern University, Evanston, Illinois 60201.*

SS2B.29 **Managematics: The Concept and Its Application,** *JACK B. ReVELLE, Dept. 65-1, General Dynamics Convair Division, Fort Worth, Texas 76101.*

SS2B.30 **An Evaluation Model for an Alcohol Safety Action Program,** *ROBERT T. RILEY and THOMAS A. WILLIAMS, University of Cincinnati, Cincinnati, Ohio 45221.*

SS2B.31 **Economies of Scale in Medical Practice,** *RICHARD M. SCHEFFLER, University of North Carolina, Chapel Hill, North Carolina 27514*

SS2B.32 **TOPS/Schedule Increases Profit: A Real Construction-Industry Example,** *ROBERT J. SCHRIER, Mid-Valley, Inc., P.O. Box 1977, Sanford, Florida 32771; and ELIZABETH A. TILLEY, Hollander Associates, Fullerton, California 92633.*

SS2B.33 **A Model for the Allocation of Ambulatory Health Care Centers in a Metropolitan Area,** *LARRY SHUMAN, University of Pittsburgh, Pittsburgh, Pa. 15213; and C. PATRICK HARDWICK, Blue Cross of Western Pennsylvania, One Smithfield St., Pittsburgh, Pennsylvania 15222.*

SS2B.34 **Effectiveness of Airmobile Services in Health Care Systems,** *AMAR J. SINGH, Case Western Reserve University, Cleveland, Ohio 44106.*

SS2B.35 **Technology and Health: Some Thoughts on Computer-Based Hospital Information Systems,** *DAVID H. STIMSON, University of California, Berkeley, California 94720.*

SS2B.36 **An LP Model for Estimating Recreation Tours on a National Forest Transportation Network,** *EDWARD C SULLIVAN, University of California, Berkeley; Institute of Transportation and Traffic Engineering, 1301 South 46th St., Richmond, Calif. 94804.*

SS2B.37 **Performance Attributes for the Radiographic Facilities Location-Allocation Problem,** *GERALD J. THUESEN, Georgia Institute of Technology, Atlanta 30032, and WILLIAM G. SULLIVAN, Medical College of Georgia, Augusta, Georgia 30902.*

SS2B.38 **Health System Ecology: An Interactive Model,** *ILAN VERTINSKY, Tulane School of Public Health, Tulane University, New Orleans, Louisiana 70118; JOHN MILSUM, McGill University, Montreal, P.Q., Canada; DEAN UYENO and HART WILL, The University of British Columbia, Vancouver 8, Canada.*

SS2B.39 **Investment Feasibility Analysis,** *RICHARD B. WILL, 1400 So Joyce St., Arlington, Virginia 22202.*

SS2B.40 **Queueing Model for a Community Health Center,** *ELIZABETH H. YEN, Grumman Data Systems Corporation, Bethpage, New York 11714.*

FRIDAY AM, October 29 Embassy Room

Session: SS3A 9:00–11:00
Abstracts: B-277

Session: SS3B 11:00– 1:00
Abstracts: B-284

Paper Fair Session 3

Chairman: ROMESH SAIGAL
School of Bus. Adm., University of California,
350 Barrows Hall, Berkeley, California 94720

Session 3 features advances in methodology.

SS3A.1 **A Bounding Minimization Problem for Primal Integer Programming,** *LARRY R. ARNOLD and MANDELL MORE, Graduate School of Business Administration, Tulane University, New Orleans, Louisiana 70118.*

SS3A.2 **Purchasing Priorities in Queues,** *K.R. BALACHANDRAN, School of Business Administration, University of Wisconsin-Milwaukee, Milwaukee, Wisconsin 53201.*

SS3A.3 **R&D Budgeting Allocation For New Product Development,** *WARREN BALINSKY, MELVIN BROWN, DONALD FRIEDEL, MILTON SCHOEMAN, School of Management, Department of Management Sciences, State University of New York, Buffalo, New York 14214.*

SS3A.4 **Development of a Methodology for Evaluating Visual Clarity Information Previews in Driving,** *VIVEK D. BHISE and THOMAS H. ROCKWELL, Systems Research Group, Department of Industrial Engineering, The Ohio State University, 1971 Neil Avenue, Columbus, Ohio 43210.*

SS3A.5 **Capital Budgeting and Sequencing of Projects with a Probabilistic Objective Function and Constraints on Risk,** *C. RALPH BLACKBURN, II, DONALD R. WOOD, JR., J. LEWIS ROBERTSON, Operations Research Group, Atlantic Richfield Company, P.O. Box 2819, Dallas, Texas 75221.*

SS3A.6 **A Generalized Dynamic Programming Algorithm,** *DAVID B. BROWN & MITCHELL OLSZEWSKI, Rutgers University, Department of Mechanical and Aerospace Engineering, New Brunswick, New Jersey 08903.*

SS3A.7 **Queues With Service in Random Order,** *GRACE M. CARTER, ROBERT B COOPER, School of Industrial and Systems Engineering, Georgia Institute of Technology, Atlanta, Georgia 30332.*

SS3A.8 **A Simulation Model to Develop Spares Inventory Aboard an Aircraft Carrier,** *SAMUEL E. CLOPPER, JR., Westinghouse Electric Corporation, MS 434, P.O. Box 746, Baltimore, Maryland 21203.*

SS3A.9 **A Two Product Production-Inventory Model With Either-Or Constraints,** *THOMAS B CRABILL, School of Business Administration, University of North Carolina, Chapel Hill, North Carolina 27514.*

SS3A.10 **More on Stochastic Single Commodity Network Flow,** *J.W. CRAWFORD, Bell Telephone Laboratories, Inc., Whippany Road, Whippany, New Jersey 07981.*

SS3A.11 **A Heuristic for the Multi-Product Single Machine Scheduling Problem,** *C. LOREN DOLL, Purdue University, Krannert Graduate School of Industrial Administration, Lafayette, Indiana 47907.*

SS3A.12 **Sensitivity Analysis for Statical and Dynamic Leontief Models,** *K. ENT, J. GETSCHMAN, V. SELMAN, 134 S. Fenwick St., Arlington, Virginia 22204.*

SS3A.13 **Quasi-Convex and Pseudo-Convex Functions on Solid Convex Sets,** *JACQUES A FERLAND, Department of Operations Research, Stanford University, Stanford, California 94305.*

SS3A.14 **A System for Information Retrieval and Analysis for College Administration,** *EDWIN C. FOUDRIAT, JOSEPH E. MATAR, Electrical Engineering Department, Marquette University, 1515 West Wisconsin Avenue, Milwaukee, Wisconsin 53233.*

SS3A.15 **Randomized Solutions for Stochastic Mathematical Programming Problems,** *STAN FROMOVITZ, University of Maryland, College of Business and Public Adm., College Park, Md. 20740; and CHAIHO KIM, Graduate School of Business Adm., University of Santa Clara, California 95053.*

SS3A.16 **The Use of Continuous Simulation Languages In the Teaching of Operations Research,** *ROBERT G. SARGENT, Syracuse University Department of Industrial Engineering, 441 Link Hall, Syracuse, New York 13210.*
University of Colorado, Boulder, Colorado 80302.

SS3A.17 **A Spare Machine Problem,** *D.P. HEYMAN, Bell Telephone Laboratories, Incorporated, Holmdel, New Jersey 07733.*

SS3A.18 **Minimal Disconnecting Sets in Directed Multi-Commodity Networks,** *JOHN J. JARVIS, School of Industrial and Systems Engineering, Georgia Institute of Technology, Atlanta, Georgia 30332.*

SS3A.19 **Revenue-Determined Adjustment Intervals,** *WILLIAM J. KENNEDY, JR.,*

Dept. of Mech. Eng., Merrill Engineering Building, University of Utah, Salt Lake City, Utah 84112.

SS3A.20 **The Application of Mixed-Integer Programming to the Analysis of Letter Processing Systems,** *MATT LIND, The MITRE Corporation, Bedford, Massachusetts 01730.*

SS3A.21 **On Applications of the Root Locus Method in Operations Research,** *E.J. MUTH, B.D SIVAZLIAN, Department of Industrial and Systems Engineering, The University of Florida, Gainesville, Florida 32601.*

SS3A.22 **Response-Variance Tradeoffs in Adaptive Forecasting,** *JOHN O. McCLAIN, L. JOSEPH THOMAS, Graduate School of Business and Public Administration, Cornell University, Ithaca, New York 14850.*

SS3A.23 **Optimum Equipment Layout,** *FARROKH NEGHABAT, Bell Telephone Laboratories, Whippany Road, Whippany, New Jersey 07981.*

SS3A.24 **A Stratified Bid Model,** *TURGUT M. OZAN, GERALD A. BIASIOLLI, Division of Engineering, Department of Industrial Engineering, St. Mary's University, 2700 Cincinnati Avenue, San Antonio, Texas 78228.*

SS3A.25 **Dynamic Programming for Efficient Tree Utilization,** *STELIOS PNEVMATICOS, STUART H. MANN, School of Forest Resources, The Pennsylvania State University, University Park, Pennsylvania 16802.*

SS3A.26 **An Optimal Procedure for Step-Wise MAD Regression Analysis,** *GARY M. ROODMAN, Amos Tuck School of Business Administration, Dartmouth College, Hanover, New Hampshire 03755.*

SS3A.27 **An Arc Elimination Algorithm for the Exact Solution of the Symmetric Traveling Salesman Problem,** *NORMAN P. SALZ, Institute for Data Research, Inc., 191 Capen Boulevard, Amherst, New York 14226.*

SS3A.28 **An Integer Programming Approach to the Reduction of Auditing Cost Constrained by Statistical Precision,** *WILLIAM G. SCOTT and J. PHILIP KILKEARY, Peat, Marwick, Mitchell & Co., 1025 Connecticut Avenue, N.W., Washington, D.C 20036.*

SS3A.29 **A Simplex-Like Algorithm for the Modular Design Problem,** *T. SHAFTEL and G.L. THOMPSON, Carnegie-Mellon University, Graduate School of Industrial Administration, Pittsburgh, Pennsylvania 15213.*

SS3A.30 **"A Predictive-Control Approach to Conversion Planning",** *HARRY M. STRONG, The MITRE Corporation, Westgate Research Park, McLean, Va. 22101.*

SS3A.31 **Linear Multiobjective Programming,** *P.L. YU, M. ZELENY, Graduate School of Management, University of Rochester, Rochester, New York 14627.*

SS3A.32 **An Evaluation of A Scheduling Algorithm Used in an Experimental Limited Purpose Time Sharing Computer System,** *HAROLD A. ANDERSON, JR., ROBERT G. SARGENT, Syracuse University, Department of Industrial Engineering, 441 Link Hall, Syracuse, New York 13210.*

SS3A.33 **Applying Computer Analysis Programs to New Areas,** *JAMES C. BOWERS and DAVID B. GOODRICH, University of South Florida, College of Engineering, Electrical & Electronic Systems Department, Tampa, Florida 33620.*

SS3A.34 **Systems-Affected Unique Single Sampling Plans For Multistage Manufacturing Connected-Unit Situation,** *SEDAT SAMI ERCAN, Roosevelt University, 430 S. Michigan Avenue, Chicago, Illinois 60605.*

SS3A.35 **Implementation of a modified parametric decomposition algorithm: Computational experience,** *ARUN K. GUPTA, Management Scientist, Burroughs Corporation, Detroit, Michigan 48232.*

SS3A.36 **A Common-Denominator Methodology For General Systems Modeling,** *J.C. O'BRIEN, 457 W. Columbia Avenue, Pomona, California 91768.*

SS3A.37 A System of Systems, *FEDERICO FRISCHKNECHT, University of Buenos Aires, Lavalle 534, Piso 6, Buenos Aires, Argentina.*

SS3B.1 A Mathematical Programming Model To Optimize the Teaching-Learning Process: The Network Model, *MARIA R. BELGARD, 64 A Escondido Village, Stanford University, Stanford, California 94305; LEO Y. MIN, School of Education, The Catholic University of America, Washington, D.C 20017.*

SS3B.2 An Economic Model For Planning Strategic Mobility Posture, *G. BENNINGTON, North Carolina State University, Raleigh, North Carolina, L. GSELLMAN and S. LUBORE, The MITRE Corporation, McLean, Virginia 22101.*

SS3B.3 Generalized Expressions for the Minimum Time Interval Between Consecutive Arrivals at an Idealized Railway Station, *DIETRICH R BERGMANN, Wayne State University, Detroit, Michigan 48202.*

SS3B.4 Resource Allocation and Scheduling of Projects Under Uncertainty, *JOHN M. BURT, JR., University of California, Los Angeles, California 90024.*

SS3B.5 Armament Development and Test Center (ADTC) Flight Test Model, *MAJOR DONALD L. OCKERMAN, 3246th Test Wing (TGTR), Eglin AFB, Florida 32542*

SS3B.6 Simulation of a Multiphasic Screening Project, *D. JAMES CROFT, University of Utah, Salt Lake City, Utah 84112; RAY MILLER, Intermountain Regional Medical Program, Salt Lake City, Utah 84112.*

SS3B.7 Lot Size Determination in Multistage Assembly Systems, *WALLACE B. CROWSTON and MICHAEL H. WAGNER, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139.*

SS3B.8 Integrated Nonlinear Optimization/Simulation, *GUY L. CURRY and RICHARD B WADSWORTH, Texas A&M University, College Station, Texas 77843.*

SS3B.9 Supply and Redistribution Rules for Multilocation Inventory Systems, *CHADRASEKHAR DAS, Case Western Reserve University, Cleveland, Ohio 44106.*

SS3B.10 A Comparison of Quantitative Forecasting Procedures, *STUART JAY DEUTSCH and KIRTIKUMAR KATKAR, Polytechnic Institute of Brooklyn, Brooklyn, New York 11201.*

SS3B.11 The Multiple Discretionary Priority Rule, *MAXIMILIAN M. ETSCHMAIER, University of Pittsburgh, Pittsburgh, Pennsylvania 15213.*

SS3B.12 The Parallel Theory for Matrices and Network Systems, *S. GAUNT, National Research Council of Canada, Ottawa 7, Ontario.*

SS3B.13 A New Spares Optimization Approach Using Inventory Modelling Techniques, *NORMAN GELLMAN and MORDECHAI LI-OR, ELTA Electronics Industries, Ltd., Ashdod, Israel.*

SS3B.14 Experimental Design for the Simulation Study of a Disk Storage Device, *ARMIT L. GOEL, P.S. NANDA, and S. MUKHOPADHYAY, Syracuse University, Syracuse, New York 13210.*

SS3B.15 GLM in Perspective, *HARVEY J. GREENBERG and THEODORE C. ROBBINS, Southern Methodist University, Dallas, Texas 75222.*

SS3B.16 The Dangers of Attractive Taxonomies, *JOHN R. HALL, JR , University of Pennsylvania, Philadelphia, Pennsylvania 19104.*

SS3B.17 Linear Programming in Electro Optical Systems Design, *R. MICHAEL HORD, Itek Corporation, 10 Maguire Road, Lexington, Massachusetts 02173.*

SS3B.18 The Effect of Repairable Spares for a Multiple-Unit Standby Redundant System, *DAVID L. JAQUETTE, and SHUNJI OSAKI, University of Southern California, Los Angeles, California 90007.*

SS3B.19 **A Basic Approach to Evaluating the Effectiveness of VFR Control Towers,** *LAMBERT S. JOEL, Applied Mathematics Division and WAYNE A. STEELE, Technical Analysis Division, National Bureau of Standards, Washington, D.C. 20234.*

SS3B.20 **A Comparison of Computation Times for Various Starting Procedures, Basis Change Criteria, and Solution Algorithms for Distribution Problems,** *DARWIN KLINGMAN, FRED GLOVER, D. KARNEY and A. NAPIER, The University of Texas at Austin, Austin, Texas 78712.*

SS3B.21 **A Multi-Plant Long-Range Capacity-Planning Model,** *P.T. LELE, Western Electric Engineering Research Center, Princeton, New Jersey 08512.*

SS3B.22 **Transportation Problem with Variable Capacities,** *BENJAMIN LEV, Temple University, Philadelphia, Pennsylvania 19122; and LEON S. LASDON, Case Western Reserve University, Cleveland, Ohio 44106.*

SS3B.23 **Cost-Effectiveness Analysis Applied to the Authorization of Information Systems Projects,** *W.R. MAKI, Weyerhaeuser Company, Tacoma, Washington 98401.*

SS3B.24 **The Production Rate of a Series of Work Stations with Variable Service Times,** *E.J. MUTH, University of Florida, Gainesville, Florida 32601.*

SS3B.25 **Stochastic Behavior of Two-Unit Standby Redundant Systems,** *TOSHIO NAKAGAWA, Meijo University, Nagoya 468, Japan, and SHUNJI OSAKI, University of Southern California, Los Angeles, California 90007.*

SS3B.26 **The Equivalence of Integer Programs to Constrained Recursive Systems,** *PATANJALI S. NANDA, Syracuse University, Syracuse, New York 13210.*

SS3B.27 **Designing Multi-Use, Multi-Facility Systems Using a Branch-and-Bound Algorithhm,** *CHARLES E. PINKUS and DONALD GROSS, The George Washington University, Washington, D.C. 20006, and RICHARD M. SOLAND, Research Analysis Corporation, McLean, Virginia 22101.*

SS3B.28 **Assembly Line Balancing Including Station Change Costs,** *F.E. PLONKA, FU-TONG HSU, KAILASH C. KAPUR, Wayne State University, Detroit, Michigan 48202*

SS3B.29 **The Miltiple Set Covering Problem: A Side-Stepping Algorithm,** *A. RAO, School of Management, Rensselaer Polytechnic Institute, Troy, New York 12181.*

SS3B.30 **Semi-Markov Processes in Evaluating Shortage Costs,** *S. SUBBA RAO and MUHITTIN ORAL, Case Western Reserve University, Cleveland, Ohio 44106.*

SS3B.31 **A Bernoulli Regression Model,** *H.C. RUTEMILLER, California State College, Fullerton, California 92634, and N.D. SINGPURWALLA, George Washington University, Washington, D.C. 20006.*

SS3B.32 **Disability Evaluation and Authorization–A Multi-Processing System,** *G. THEODORE SAFFRAN, SSA Operations Research Staff, (AM) Social Security Administration, Baltimore, Maryland 21235.*

SS3B.33 **Optimal Selection Among Project Alternatives,** *M. SEGAL and S. HALFIN, Bell Telephone Laboratories, Incorporated, Holmdel, New Jersey 07733.*

SS3B.34 **Operations Research for Risk Analysis Evaluation,** *JERRY SELMAN, U.S. Army Munitions Command, Dover, N.J. 07030; and VICTOR SELMAN, 134 South Fenwick St., Arlington, Virginia 22204.*

SS3B.35 **Feasibility of Regular Multidimensional Assignment Problem,** *MOHAMMED M. SHAMMA, University of Cincinnati, Cincinnati, Ohio 45221.*

SS3B.36 **Tanker Berth Simulation,** *S.J. SPIERER, Mobil Oil Corporation, 150 E 42nd Street, New York City, New York 10017.*

SS3B.37 **Elimination Methods in the m x n Sequencing Problem,** *WLODZIMIERZ SZWARC, University of Wisconsin, Milwaukee, Wisconsin 53203.*

SS3B.38 **Optimal Pricing Rules for Stochastic Resource Allocation,** *G THOMAS, University of Hawaii, Honolulu, Hawaii, and G.W. WRIGHT & A. WHINSTON, Purdue University, West Lafayette, Indiana 46205.*

SS3B.39 **Optimal Policies for Proportionately Stocked Products,** *ALAN C. WHEELER, Southern Methodist University, Dallas, Texas 75222.*

SS3B.40 **Shop Sites and Customer Behaviour Pattern,** *Q.A.M.M. YAHYA, 96 Bangalore Town, Karchi–8, Pakistan.*

SS3B.41 **Finding All Shortest Paths From a Fixed Node in Non-Negative-Distance Networks,** *JIN Y. YEN, University of Santa Clara, Santa Clara, California 95053.*

SS3B.42 **Sequencing N Jobs, with Stochastic Processing Times, on Two Machines,** *A.A. CUNNINGHAM and S.K. DUTTA, Department of Industrial Engineering, University of Toronto, Toronto, Canada.*

SS3B.43 **Network Model for Transportation System,** *EUGENE E. PAYNE, Electronic Data Systems, Exchange Park, Dallas, Texas 75235.*

SS3B.44 **The Design of the National Right-to-Read Effort,** *ROGER L. SISSON, Government Studies and Systems, Inc., 3401 Market Street, Philadelphia, Pa. 19104.*

SS3B.45 **Multicommodity Networks with Resource Constraints: The Generalized Multicommodity Flow Problem,** *RICHARD D. WOLLMER, Department of Operations Research and Statistics, California State College, Long Beach, California 990801.*

FRIDAY PM, OCTOBER 29 **Embassy Room**

Session: SS4A 1:00–3:00
Abstracts: B-293

Paper Fair Session 4

Chairman: STEVEN LIPPMANN
Graduate School of Bus. Adm., University of California, Los Angeles, California 90024

Session 4 features Ecology and Public Utility Applications.

SS4A.1 **Problems of Identification of Social Cost,** *HOSSAIN AHMADI, Polytechnic Institute of Brooklyn, 333 Jay St., Brooklyn, New York 11201; and JOHN VAFAI, Rutgers University, Newark, New Jersey 07102.*

SS4A.2 **Generalized Expressions for the Minimum Time Interval Between Consecutive Arrivals an Idealized Railway Station,** *DIETRICH R. BERGMANN, Wayne State University, Detroit, Michigan 48202.*

SS4A.3 **Systems Engineering Develops a Highly Mechanized Bulk Mail Handling Facility,** *ROBERT J. CARDINAL, Lester B. Knight & Associates, Inc. 549 W. Randolph, Chicago, Illinois 60606.*

SS4A.4 **Mathematical Approaches to Timber Management,** *BARNEY L. CAPEHART, University of Florida-GENESYS, Orlando, Florida 32809; and RICHARD J. TAYLOR, Orlando Data Center, Martin Marietta Corp., Orlando, Florida 32809.*

SS4A.5 **An Optimum Spraying Policy for the Control of Insect Population,** *SAMPRIT CHATTERJEE, New York University, 100 Trinity Place, New York, New York 10006.*

SS4A.6 **State Inspection of Automobiles to Monitor the Performance of Exhaust Gas Emission Control Systems,** *FRANK A. COLLINS and GERALD J. THUESEN, Georgia Institute of Technology, Atlanta, Georgia 30332.*

SS4A.7 **A Continental Energy Policy and Planning Model,** *J.G. DEBANNÉ,* University of Ottawa, Canada.

SS4A.8 Minimizing Regional Pollution Control Costs, *ROLF A. DEININGER and SHIAW Y. SU, School of Public Health, The University of Michigan, Ann Arbor, Michigan 48104.*

SS4A.9 Economic Model of Transportation in a Small Federal Recreational Area, *LUCIEN DUCKSTEIN, WALTER D. THOMPSON, and GARY B. WILLIAMSON, University of Arizona, Tucson, Arizona 85721.*

SS4A.10 Collective Utility: A Systems Approach to the Use of Natural Resources, *EDWIN DUPNICK, The University of Arizona, Tucson, Arizona 85721.*

SS4A.11 Cost of Optimization for the Design of Trickling Filtration Process in Water Pollution Control, *G ALLEN ELLIFF, CHIA SHUN SHIH, and W.L. MEIER, JR., Texas A&M University, College Station, Texas 77843.*

SS4A.12 Simulation of Parcel Sorting Factory for the U.S. Post Office, *RONALD A. HABERMAN, University of New Haven, West Haven, Connecticut 06516.*

SS4A.13 The Evaluation of Product Bans in the Public Interest, *JOHN R. HALL, JR., Management and Behavioral Science Center, University of Pennsylvania, Philadelphia, Pennsylvania 19104.*

SS4A.14 Methods of Problem Solution Applied to the Development of a National Bulk Mail System, *RONALD W. HARDY and TERRELL J. HARRIS, Lester B. Knight & Associates, Inc., 549 W. Randolph, Chicago, Illinois 60606.*

SS4A.15 Framework Model for a Nuclear-Agro-Industrial Complex, *SAYEED HASAN, RICHARD B. WADSWORTH, WILBUR L MEIER, JR., Texas A&M University, College Station, Texas 77843.*

SS4A.16 Interdisciplinary Solution of U.S. Post Office Safety Problem, *LESTER KOLOM, Post Office Department, 433 W. Van Buren St., Chicago, Illinois 60699.*

SS4A.17 Development and Application of Procedures for Testing Cost Functional Forms: The Development of an Optimal Water Quality Treatment Program, *JAMES R MARSDEN, University of Kentucky, Lexington, Kentucky 40506; DAVID PINGRY, Virginia Polytechnic Institute, Blacksburg, Virginia 24061; and ANDREW WHINSTON, Purdue University, West Lafayette, Indiana 47907.*

SS4A.18 Detection of Power-Plant Thermal Pollution in Rivers by Communication Systems Techniques, *J.C. MAXWELL, LELAND L. LONG, B.E. GILLETT, University of Missouri-Rolla, Rolla, Missouri 65401.*

SS4A.19 Comparison of Water Pricing Structures from a Collective Utility Viewpoint, *BILL METLER and LUCIEN DUCKSTEIN, University of Arizona, Tucson, Arizona 85721.*

SS4A.20 Systems Analysis of Urban Water and Liquid Waste Management: A Case Study, *JOHN J. McCORD, General Research Corporation, P.O. Box 3587, Santa Barbara, California 93105.*

SS4A.21 The Applications of Quantified Expert Judgment in Cost-Effectiveness Analysis of Environmental Monitoring Systems, *GAYLORD M. NORTHROP, EARL L. DAVIS, EDWARD R. SWEETON, The Center for the Environment and Man, Inc., 275 Windsor St., Hartford, Connecticut 06120; and CDR WILLIAM F. MERLIN, NASA Mississippi Test Facility, Bay St. Louis, Mississippi 39520.*

SS4A.22 Impact Statements on Nuclear Power: 1970s and 2070s, *JERRY S. OLSON, Oak Ridge National Laboratory and University of Tennessee, Oak Ridge, Tennessee 37830.*

SS4A.23 Modelling Experience on the University of Michigan Sea Grant Project, *R L. PATTERSON, University of Michigan, Ann Arbor, Michigan 48104.*

SS4A.24 SERF: A System for Equipment Requirements Forecasting, *R. JOHN PREVOST, Southwest Research Institute, P.O Drawer 28510, San Antonio, Texas 78228.*

SS4A.25 Space-Time Sampling of Ecological Systems, *HASSAN QUASHU, LUCIEN DUCKSTEIN, CHESTER KISIEL, University of Arizona, Tucson, Arizona 85721.*

SS4A.26 Cause and Effect Diagrams as an Aid to Systems Formulation in Solid Waste Management, *ADARSH SAIGAL and DILEEP SULE, Louisiana Tech University, Ruston, Louisiana 71270.*

SS4A.27 The Potential of Dynamic Programming in Assessing the Crises of Water Pollution, *CHIA SHUN SHIH and JOSEPH K. GARNER, Texas A&M University, College Station, Texas 77843.*

SS4A.28 Environmental System Synthesis, *MAURICE H. SIMPSON, United States Army Combat Developments Command, Institute of Systems Analysis Group, Fort Belvoir, Virginia 22060.*

SS4A.29 Extreme Values from a Lognormal Law with Applications to Air Pollution Problems, *N.D. SINGPURWALLA, The George Washington University, Washington, D.C. 20006.*

SS4A.30 Techniques for Selecting Particulate AIr Pollutant Control Equipment, *CHARLES W. STONE, University of Illinois, Urbana, Illinois 61801.*

SS4A.31 Optimal Operating Policies for Multiple-Purpose, Multi-Reservoir Systems, *SHIAW Y. SU and ROLF A. DEININGER, The University of Michigan, Ann Arbor, Michigan 48104.*

SS4A.32 A Linear Programming Model for the Selection of Refuse Collection Schedules, *M. TANAKA, Wayne State University, Detroit, Michigan 48202; and J.E. QUON, Northwestern University, Evanston, Illinois 60201.*

SS4A.33 The Systems Model in Water Resources Planning, *BILLY M. THORNTON and W.L MEIER, JR., Texas A&M University, College Station, Texas 77843.*

SS4A.34 Management Science and Gaming: An Aid to Decisionmaking in Ecology, *P.N. WAHI and T.I. PETERSON, IBM Cambridge Scientific Center, Cambridge, Massachusetts 02139.*

SS4A.35 Centralization of Waste Treatment Facilities, *MARTIN P. WANIELISTA and CHRISTIAN S. BAUER, Florida Technological University, Orlando, Florida 32816.*

SS4A.36 Modern Theory of Filtration Process on Water Pollution Control and its Optimization by Combined Mathematical Programming Techniques, *DUANE J. WRAY, Captain, USAF, Senior Highway Advisor, Danang Highway Detachment, and CHIA SHUN SHIH, Texas A&M University, College Station, Texas 77843.*

Abstracts

FORMAL SESSIONS

THA1.1 Orchestrating Technology with Other Means to Solve Societal Problems, GABOR STRASSER.

The environmental crisis has evolved from a series of complex, interrelated events and circumstances rather than from any single cause. In turn, the solution to this crisis must draw upon the contributions of many disciplines and professions. The function of the systems approach is to integrate these interdisciplinary contributions. The integration is not restricted to design alone, but must span the entire spectrum from goal setting to actual implementation of programs. This paper will introduce the following six papers of the session, each of which focuses on a well-defined societal problem. Following these six papers, this paper will then conclude by attempting to synthesize common elements from all the papers that are necessary for a successful conclusion.

THA1.2 Integrated Population/Environmental Policy—Needs and Constraints, R.W. LAMSON.

This paper will examine a national policy for population/environment by posing such questions as the following: What are we doing? What is our substantive approach to the problem? How and by what means and institutions are we going about implementing solutions to the population/environment problem? These kinds of questions will be addressed on a number of levels—intellectual, operational, and institutional.

THA1.3 Social Priorities: The Dilemma of Quality versus Quantity, MARTIN V. JONES.

This paper will examine selected multi-dimensional issues that would be raised by massive efforts to lengthen the average life span. Factors that have historically contributed most to increasing average longevity as well as factors which contribute most to mortality will be reviewed. High potential payoff areas for the future expenditure of research funds, and for concerted public action aimed at extending longevity by changing social behavioral patterns will be enumerated. Potential secondary consequences of alternative public action options to extend longevity will also be identified.

THA1.4 Urban Transportation, CHARLES A. ZRAKET.

Problems of congestion, delay, noise pollution, ugliness and unprofitability will be examined as well as the fragmented character of the transit industry—over 1,000 companies throughout the country. Neither technology nor service has changed materially since the advent of the motorbus and the subway. Needed innovations concerning high labor operating costs and high capital investments will be addressed. This approach will open a Pandora's Box from which certain relevant but incommensurable considerations as the following are likely to spill out: Land Use, Housing and Unemployment Patterns, Safety, Pollution, Noise, Economic Effects, etc.

THA1.5 The Automobile and Air Pollution– "Who Won the War?", S. WILLIAM GOUSE.

It is reasonably certain that the mid-70's will see the marketing of virtually pollution-free automotive vehicles. This will have been accomplished by an adversary procedure that essentially ended with the Clean Air Act Amendments of 1970. The cost and benefits of this action, and the distribution of these costs and benefits are yet to be determined. This action will probably be justified on the basis that it was the first time that society chose to confront a problem of this nature. There is much to be learned from the history of this confrontation. Unfortunately, at present, little has been learned from the confrontation that has taken place in the area of automotive air pollution.

THA1.6 The Practical Application, from Within the University, of Interdisciplinary Approaches to Problems of Municipalities, ROBERT NATHANS.

The university's role in dealing with public service problems cannot be one of mere problem solving; it must go well beyond this. It must seek to collaborate with the research and planning staff of regional and local governments in: (a) designing and implementing solutions that fall within the economic and political constraints, as well as (b) designing around and modifying these constraints. Simultaneously, we must begin to train new kinds of technologists. Case histories will be presented based upon the first formative year of the Urban Science and Engineering activity at the State University of New York.

THA1.7 Health Care for the 1970's, RAPHAEL J. SALMON.

National thinking with respect to medical and health care services has undergone drastic changes during the past decade as illustrated by numerous new legislative and programming efforts. These have served to highlight the difficulty of achieving comprehensive high quality medical care for all Americans. Services have frequently been inadequate and quality difficult to evaluate. Medical care costs have soared. It has become increasingly evident that there are critical problems in the management of our entire health care system. We have reached a point where it is difficult to separate health care as a national priority from health care as a major political issue.

THA2.1 Transaction Based Statistics for Criminal Justice Management Decision Making, STEVE E. KOLODNEY and PAUL K. WORMELI.

Project SEARCH began as a multi-state effort designed to develop a prototype computerized criminal justice information system. The second of its two major objectives was to design and demonstrate a computerized criminal justice statitsitcs system.

Sets of annual, single-agency criminal process courts were rejected as adequate descriptions of criminal justice system activity A more useful description of activity is produced by reviewing the total experience of individual offenders who enter and proceed through the criminal justice system. This approach produces three kinds of needed information: elapsed time to process, re-circulation of offenders (i.e., recidivism), and reconciled input-output of agencies.

This step toward a criminal justice statistics system is presently being implemented at the state level of five participating states.

THA2.3 Private Police in the United States, JAMES S. KAKALIK and SORREL WILDHORN.

With rising crime rates, fear of crime, and economic losses to crime, investment in private security has risen rapidly over the last few years. This paper summarizes the results of a comprehensive study of private police in the United States. It provides a profile of private security today–its growth, roles and functions, the type of personnel employed in it, their training, their legal powers, how they interact with regular law enforcement, how private security is regulated today, and some of its problems. Finally, considering the benefits, costs, and risks to society of private security, tentative guidelines are offered for its regulation and operation.

THA2.4 Computer-Assisted Dispatching Systems, ROBERT J. RIEDER.

Assignment of police resources to provide patrol and emergency services required in most cities is a matching task not unlike that for which military command and control systems have evolved. Drawing upon this technology and modern information systems techniques, computer-assisted dispatching systems have evolved as an aid to police departments. This paper describes one such Computer-Assisted Dispatching System being developed for the Tulsa Police Department by NARISCO. The system involves the use of a minicomputer and several cathode ray tube terminals used at the dispatcher stations and complaint-taker stations. The system provides rapid and timely information regarding crimes in action, police assignments, and selected criminal records.

THA2.5 The Application of Operations Research to Forensic Science, HAIG BOHIGIAN.

The administration of a forensic science laboratory, the forensic investigation of evidence, and the documentation of findings for trial, all represent a wealthy source of problems amenable to the methods of operations research. This paper illustrates some of these problems that have been resolved through the application of operations research, as well as identifying other forensic science problems that are likely candidates for evaluation by operations research techniques.

THA4.1 Systems Approaches for Development, GUY B. GRESFORD.

The management sciences can make an increasingly important contribution when applied to some of the critical problems of the developing world. It is in the developing countries that the majority of the population of mankind on this planet is to be found and where projections indicate the greatest growth in this population will occur. Some of the approaches being developed within the management sciences can assist in a more effective definition of some of the critical problems confronting the developing countries—"Systems analysis approaches" will undoubtedly be called upon more and more because of the need to handle complex questions that are highly interdisciplinary and interrelated with other problem areas. Most of the examples involving use of systems analysis approaches have been heretofore in the aerospace/defense fields. The concepts, and some of the techniques, should be applied to the problems of the developing countries, although this will need a reorientation and a further development of the underlying methodology. Special reference will be made to the problems posed by telecommunications and data processing. The U. N. Advisory Committee on the Application of Science and Technology to Development has recognized this and has stimulated some activities in this field. Within the U. N. family of organizations, there is the beginning of some preliminary work in this field and the paper contains some illustrations of these efforts.

THA4.2 Computers and Data Bases as Tool for Communications and Development, WILLIAM F. MILLER.

A consideration of the behavioral, technical and systems problems that arise in a variety of uses of the computer for communication, teaching and programmed development. To include the technical problems of data-based development including integrity and privacy, as well as the problems of reliability in communication networks being attached to computers. The presentation also addresses the behavioral aspects of learning from machines, and the cost of development of different kinds of systems.

THA4.3 The Role of Satellites in Telecommuncations in the Developing Countries, BRUCE LUSIGNAN.

Within the last six years, the strength of signals available from telecommunications satellites has increased by a factor of 10,000. Ground receivers capable of receiving signals have decreased from $8,000,000 to less than $300. These changes have dramatically increased the capability of satellites to provide economical television distribution and telephone communications to rural areas in developing countries. These capabilities are

now being considered in advanced planning efforts of many countries for education and communications.

THA5.1 The Use of Computer Simulation in Airport Airside Planning, D.B. ADARKAR.

This paper discusses the application of Monte Carlo Simulation to the design of the Airport Airside, i.e., runways, taxiways, aprons and gates. The factors influencing airport airside congestion and delay are discussed with illustrations from Douglas parametric studies using the configuration of San Francisco International Airport. Certain limitations in the use of such simulations are urged pending further research. It is emphasized that parametric studies are important, in view of the uncertainty in the data available for long-range planning. The usefulness of a graphics/display of the computer simulation as a means of involving relatively non-technical airport management is pointed out.

THA5.2 The Planning Process in the California Division of Highways, GEORGE WOFFORD.

During the process of planning for our freeways, we are confronted with many problems. Among these are: How to obtain meaningful citizens' involvement throughout the planning process in order to identify community goals and concerns. How to broaden our choices to include mass transportation, freeways, conventional highways, and local streets. How to identify the system that will best serve the needs of the communities, the region, and the users. How to bring together the many divergent interests of all of the communities affected. How to coordinate highway planning effort with total comprehensive planning so that they mutually support each other. All of these problems, as well as others, must be solved if we are to properly provide for the future.

THA5.3 New Transportation Concepts for Urban Growth Control, NORMAN V. PETERSEN.

The speaker discusses the interrelationships of transportation systems and urban development and urges consideration of new societal planning concepts to simultaneously control, or relate, both transportation demand and urban form. These concepts basically involve the distribution of transportation demand over time and space. The potential payoff in lowered transportation demand by such planning alternatives as shortened work week, shifts in daily work schedules, decentralization or dispersal of plants or employment centers, reliance on part-time home employment, etc., are described. Continual expansion of the journey-to-work distance promoted by "giantism" and "specializations" in employment centers, both public and private, and the counter growth toward larger city boundaries is central to the problem of excessive transportation demand for employment purposes and its effect on urban deterioration. Distribution over time by simply a four-day work employment model can accrue a lowered transport demand in excess of 40 percent. Decentralization of employment centers could exceed even that gained for a four-day work week.

THA5.4 An Evaluation of Conventional and Interactive Planning Procedures, J. D. DRACHMAN.

The time-sharing computer concept has been in existence for some time. However, not until recently has the concept become popular enough to allow the economic feasibility of quality controlled installations with adequate virtual core capabilities and good response times. The generalized subject of interactive planning is a natural outcome of the availability of such remote control terminals with access to large memory banks. The idea is particularly applicable to transportation planning since presently recognized conventional methods and techniques have only been possible with the use of digital computers capable of storing regional transportation networks. Interactive transportation planning procedures allow the interphasing of the planner with the data bank and produces quasi-instantaneous responses to planning questions. Conventional planning procedures are generally assumed more accurate. The two planning philosophies are compared and available methodology and procedures are presented.

THA5.5 Contingency Headway Analysis for Ground Transportation Systems: An Analytical Approach, DAVID B. SMITH and JONATHAN S. YORMARK.

Systems analysis of ground transportation systems is necessarily influenced by safety requirements. Two primary factors affecting the system capability are vehicle headways and control system performance. Since safety criteria will often define a lower bound on system headways, a careful analysis of the system capacity/safety tradeoff must be made. A new measure of safety is discussed here and used in deriving a general mathematical model of the dynamic relationship between vehicles. Single vehicle failure contingencies are then examined and a simple general analytical solution for minimum safe headways is developed. An actual application is used to demonstrate how this simple result is useful for performing analysis required to establish system speeds, acceleration-/deceleration profiles, station design features, and certain operational strategies.

THA6.1 Manned Earth Orbital Research and Applications Investigations, KENNETH A. STONE.

This paper gives emphasis to the international utilization of facilities and laboratories in near-earth orbit to produce research leading to near-term applications.

THA6.2 Typical Problems in Bridging from Space Technician to User Communities, ALLAN MUIR.

Earth observations is an evolving program concerned with the application of certain specific space technologies to the benefit of user communities. There are some general aspects of the need to bridge from the space technicians to the user community. Some general rules on the brokerage function required have been developed in the last couple of years. However, the variety of the problems involved in the brokerage function and the need for a truly multiple disciplined team can be best illustrated through a few specific examples. From these examples, further insightful generalizations can be drawn about the character, extent, difficulties, and potential solutions to the technology transfer problem.

THA6.3 Utilization of Meteorological Satellite Data with Emphasis on the User's Needs, DELBERT B. SMITH.

This paper will consider the rationale of research being carried out at the Space Science and Engineering Center of the University of Wisconsin pertaining to users of meteorological satellite data. The emphasis of the paper will be on the need for a multi-disciplinary team approach to user analyses and the effect that this has on the development of satellite hardware. It is important that meteorological satellite systems development be responsive to user's needs, since ultimately it is the satisfaction of these needs that justifies the system. There should be an ease of access to the data, and there should be sufficient flexibility in the system to enable it to be altered to meet new and changing user's needs. The paper will consider the results of the Wisconsin study and its application to related areas.

THA6.4 The Economy, Technological Progress, and R&D—Some interactions, ROBERT E. ROBERTS, HOWARD GADBERRY, and ROBERT E. FLEISHER.

This paper presents the findings of an investigation into the amount of economic growth traceable to technological advances during the aerospace era, plus estimates of the R&D payoffs during the same period. The analyses were conducted at the macro economic level. Some of the complex relationships inherent in the movement of technologies to commercial applications are illustrated by examples drawn from a case study of the role of NASA and NASA contractors in the achievement of commercial communications satellites.

THP1.1 Welfare Reform and the Urban Crisis, JODIE ALLEN.

This paper examines the potential impact of proposed federal initiatives in the area of welfare reform on the problems of our major cities. Two types of impact are explored—the potential fiscal relief to cities and states resulting from increasing federal

assumption of the welfare burden; and, in greater detail, the resulting changes in the income distribution of the populations of these cities. The Current Population Survey data base is used to examine distributions of benefits among large populations within central cities and major SMSA's under alternative assumptions as to the structure of the income maintenance plan considered and the level of unemployment in projected time periods. Available data from income maintenance experiments are also used. Given the current income levels of the "poverty" population in our cities, the issue is raised of whether national income maintenance reform is being oversold, at least in the short run, as a solution to the urban poverty problem.

THP1.2. Federal Programs and Environmental Problems in the City, JOHN DEUTCH.

Recent federal initiatives in environmental quality are reviewed with particular emphasis on organizational changes, recent legislation, and the budgetary implications of the administration's environmental programs. Attention is focused on the environmental problems faced by major urban governments and the degree of assistance likely to be forthcoming from the present federal efforts during the next several years. The specific impacts of these developments on city governments and urban areas are assessed. The discussion raises several questions about the present program and suggests a number of important problems for future research.

THP1.3. Systems Effects of Revenue Sharing, CHARLES GOETZ.

Revenue sharing has been discussed primarily from the standpoint of its effects on individual government units. This discussion has largely ignored the systematic impact that revenue sharing will have on the aggregate behavior of government units viewed as components of a state and local governmental network. The particular form of a revenue sharing formula may set up incentives for governments to alter their behavior in ways not foreseen in the formulation of the legislation. Moreover, many of the system effects would probably be judged as leading to a deterioration in the environment of urban public goods decision making. This paper focuses on these aspects of revenue sharing.

THP1.4. Urban Health Problems: New York City Perspective, ROBERT HARRIS.

The urban health crisis has two basic components: the first, is the very large concentration of low income people who have inadequate access to services of all sorts. With this concentration of the poor come all of the attendant social, emotional, and physical ills of the poor, amplified by congested living conditions. The second component of the problem is the medical care delivery system which, in general, is fragmented, inefficient and not very responsive to community needs. In combination, these two problems generate a crisis in health care in New York City. This experience duplicates and, to some extent, presages the condition of other urban areas. Possible solutions are discussed, including recent federal initiatives as well as other alternatives.

THP1.5. Post-Secondary Education and the City, ALICE RIVLIN.

American higher education, both in location and structure, is to a great extent a legacy of an earlier era when: (1) population was scattered in small towns and rural areas; (2) most people had limited access to books and other sources of information; (3) higher education was primarily a preparation for professional careers for a small proportion of the population. In this era, residential colleges for young people, with their rural settings and their lecture classes, were appropriate and not inordinately costly. But now, most people live in and around cities. It is feasible for most of them to commute to a college or university. Moreover, higher education is no longer limited to the few (indeed, the demand has been growing fastest among the urban poor, especially minorities). The lecture method is no longer a uniquely satisfactory or an efficient way of delivering information. Moreover, increased leisure and the pace of change make education at later stages in life both attractive and necessary. This paper considers the options open to cities in providing this new kind of education to younger and older students.

THP3.1. Problems of Major Systems: The Post Office, ROBERT H. COHEN and THOMAS WHITE.

In many ways, the U. S. Post Office is the largest system in the world. The sheer size of the current postal operation—more than 85 billion pieces of mail delivered annually through 33,000 post offices employing 750 thousand workers with an annual budget of $8 billion—invites bold innovation in the search for better service and lower costs. Toward this end, the Congress has created the U.S. Postal Service, a new public corporation. This new organization, freed from traditional political constraints, provides an opportunity for major innovation, both organizational and technological, in the postal function of the Government. This session examines some of the most critical characteristics of postal operations and presents some analytical solutions which have been developed to meet them. In addition, the form of the Postal Service of the future is explored, both in terms of the application of current and advanced technologies and the socio-economic environment in which the Post Office will function.

THP3.2. The Postal Service and the Future Environment, WILLIAM J. SULLIVAN.

Communications and materials handling technologies are changing rapidly. As the world's largest handler of hard-copy communications, it is critical for the Post Office to exploit fully the opportunities offered by these advances. An initial goal is to improve traditional services without increasing costs by utilizing available technologies, in some instances as joint ventures with industry (the mailgram service which delivers Western Union telegrams with Postal Service carriers). For the longer range, technologies not yet fully developed are being examined (facsimile mail transmission). By the year 2000, it is conceivable that mail may be transmitted via satellite or through coaxial cables directly to homes. The socio-economic sphere is of concern as well. The Postal Service must compete in the labor market where changes in composition and attitude can be discerned.

THP3.3. The New National Bulk Mail System, GEORGE R. CAVELL and JERRY A. EDGERTON.

The Postal Service has recently instituted a major modernization program for bulk mail (i.e., 2nd, 3rd, and 4th class), aimed at reducing operating costs and improving service. This study contributed to the design of a new network of 21 bulk mail centers, and was part of the basis for the decision to implement this network by 1975. Basic to the program is the definition of the bulk mail network, which is composed of large, highly automated processing facilities and connecting links of national and local transportation. The discussion of the network definition problem includes the number, capacity, location, and linking of bulk mail centers to achieve economies and service improvements. Results are presented in terms of cost tradeoffs between processing, transportation, and service alternatives.

THP3.4. Postal and Telephone Networks. Some Similarities and Differences, RONALD ABLER.

The static spatial structures of postal and telephone networks are similar despite their physical differences and the form of the information moving through them. Structural changes in the two networks are also analogous, making it possible to use the systems as models and predictions of each other. Both networks have evolved as compromises between a tree-like structure, which minimizes the number of links needed to connect a set of places, and a more completely connected network, which minimizes switching (or sorting). Network structures respond to changes in the relative costs of links (or transportation) and switching.

THP3.5. Letter Mail Sorting: An Examination of Cost and Service, ROBERT COHEN, CHARLES McBRIDE, and THOMAS WHITE.

The major variable cost in the U. S. Postal Service is sorting letter mail. In recognition of this problem, the Postal Service has inaugurated a major research program to mechanize this activity. This study develops a generalized set of procedures for evaluat-

ing alternative mechanization. Methods are developed for determining current costs and the effect of the level of service is examined. The procedures also include a linear programming model which maximizes savings from mechanization, given service constraints and hourly and daily volume fluctuations of different types of mail. Code sort systems, a prime mechanization candidate, is evaluated using this methodology.

THP4.1. Evaluation of Economic Development on Indian Reservations, BARRY T. KIBEL.

During the first half of 1971, an in-depth evaluation of economic development activities, past and current, on 12 Indian reservations was undertaken. The methodology focused on both existing income and its sources and upon the "potential" of the given reservation to develop further economically. A scoring system was devised for translating findings into two numerical descriptors, one for income generation and a second for economic development potential. Included were bonuses for environmental difficulty, private investment generated, and Indian entrepreneurship encouraged; and discounts based upon likely stability of various undertakings. This methodology will be presented in detail together with relevant findings and conclusions drawn.

THP4.2. An Evaluation of Selected Growth Center Strategies for Economic Development, RAYMOND H. MILKMAN.

Methods for determining the effectiveness of the Economic Development Administration's growth center strategy is described in this paper. The presentation focuses on the objectives of that strategy, and the effectiveness of particular federal investments in achieving those objectives. Programs for insuring spillover of benefits to the rural hinterland are suggested. Possible criteria for designating growth centers are also discussed.

THP4.3. An Evaluation of Selected Training Activities Designed to Stimulate Economic Development, HOWARD L. WALTON.

This paper will describe the effectiveness of vocational schools in furthering the economic potential of underdeveloped areas of the United States. The data base consisted of ten schools in areas of high unemployment or low median family income. Effects of these schools on the areas' underemployed and unemployed population will be described in terms of changes in the employment and income profile of the trainees. Observations concerning the coordination of activities of the vocational schools with local economic development efforts will also be made. The impact of those schools located in so-called "growth centers" on surrounding lagging counties will be described. In addition, appropriate measures of effectiveness will be debated, for example, county vs. project, trainee vs. community, short-term vs. long-term. Various organizational structures for management of the schools will be described, and subjectively related to effectiveness.

THP4.4. Some Issues in the Evaluation of Rural Industrial Development Programs, H. LOUIS STETTLER, FREDERICK T. SPARROW, and WILLIAM H. OAKLAND.

In the evaluation of an OEO-sponsored program to foster industrial development in a four-county rural area of North Carolina, three questions of broader significance were encountered. First, in the absence of the program, at what rate would industrialization have occurred? Second, what is the labor force response to new job openings? In particular, what interpretation must be given to (a) the unresponsiveness of the unemployment rate to new jobs and (b) the high prior employment rate experienced by employees of the new firms? Third, since many view the purpose of rural development to be the stemming of outmigration, what is the impact of new employment on migration levels?

THP5.1. Highway Safety Planning—A View from the Federal Level, CHARLES H. HARTMAN.

THP5.2. Highway Safety Planning—As Viewed from the State Agency Level, RONALD S. COPPIN.

THP5.3. Highway Safety Planning—The View from the University Setting. B. J. CAMPBELL.

THP5.4. Highway Safety Planning—As Viewed by the Automotive Manufacturer, RICHARD E. KIMBALL.

The above papers will discuss highway safety planning from their respective institutional viewpoints. They will identify key issues, how they are now being handled, the way they should be dealt with in the future, and the major obstacles to progress.

THP6.1. The DD-963 Class Ship—A Major System, FRED KOSOFSKY.

This presentation will review the development of the DD-963 Class Ship through the Contract Definition process. The objective of the presentation is to describe the procedure by which an optimized design was achieved, that is, a ship meeting all specified requirements, at least life-cycle costs. The presentation will include the following topics: (a) Contract Definition, (b) Requirements and constraints imposed by the Navy; (c) Ship characteristics and performance parameters assigned to the designer for optimization; (d) Measures of effectiveness and costs; (e) Factors affecting the design, (f) Tools and techniques employed in this optimization; (g) Key decisions; and (h) The resulting design. It is shown how the disciplines of naval architecture and marine engineering are combined with techniques of operations analysis to achieve an optimum Naval combatant ship.

FA1.1 Total Conservation, An Evolving Concept, MICHAEL McCLOSKEY.

Implementation of conservation policies requires development of understanding between the lay community, technical community, and the Government. The developing discipline of conservation requires support from varied elements of society, requiring both the conservationist and technician to develop an understanding of diverse points of view. This paper will discuss the relationship of the conservationist with the technical community in their evolving roles in society.

FA1.2 The Oceans: Putting it all Together, WESLEY A. MARX.

The subject of this paper is the ocean as a natural system with implications for national and international management strategies. The topics covered include nature and scope of physical and biological interactions (including marine processes that extend inland), alterations generated by man-made activities, and social and political ramifications of these alterations. The problem of generating strategies of compatible use for marine activities with a global impact are described and trends identified. Oceanic oil development is one of the examples discussed.

FA1.3. Undesirable Feed-Back from Human-Modified Ecosystems, CHARLES F. BENNETT.

Other organisms, as well as man, may modify their ecosystems. Only man can conciously monitor his environment and alter his actions in response to undesirable feed-back resulting from his modifications. This paper will review some examples of undesirable feed-back resulting from environmental changes. It will show the need for an ecology which includes inputs from social science and the humanities. Systems models of the environment, particularly urban ecosystems, frequently do not include important human parameters.

FA1.4. Modelling of a Complex Ecosystem: Lake George, New York, J.W. WILKINSON and R.A. PARK.

The Lake George Drainage Basin, with its compactness, varied land uses and

lake heterogeneity, provides a natural laboratory for generating data to help in the interactive process of building and evaluating models of a complex ecosystem. This paper will discuss the building of conceptual models, the procedures that have been helpful in modelling the compartments and the interfaces among several compartments, the use of such a characterization of the ecosystem to aid in planning data collection and the building of an accessible data bank that permits efficient use of all data.

FA1.5. Collective Utility and Cost-Effectiveness in Natural Resource Management, LUCIEN DUCKSTEIN and EDWIN DUPNICK.

Collective utility and cost-effectiveness, two approaches to the management of natural resources, such as water, air or mineral deposits, are compared from the viewpoint of philosophy, goals, statement of hypotheses, and data requirement. Collective utility models aggregate individual satisfaction functions and revenue of firms in dealing with incremental allocation of resources and seem appropriate to study both horizontal and vertical externalities at a regional level. Cost-effectiveness techniques are suited to design a system to reach a certain goal, provided alternative systems and effectiveness criteria exist: they require more specific data and looser hypotheses than collective utility models.

FA1.6. An Application of Systems Dynamic Modelling to Energy Systems Planning, JACK BYRD, JR., LEO A. SCHRIDER, and R. DAVID HAYNES.

The systems dynamics concepts developed by Jay Forrester have been examined in a study of an energy systems model. The relevance of this approach is examined with particular emphasis given to the manner in which systems dynamics concepts can be used in an area of activity in which decisions are fragmented and uncoordinated. The system dynamics model also gives insights into the problems which need to be examined by a national energy commission.

FA1.7. Technology Assessment: Fond Hopes and Rational Expectations, DONALD E. CUNNINGHAM and DAVID M. GLANCY.

From all segments of our society are increasingly heard expressions of grave concern over the effects of technology on the environment and the quality of life itself. There are also some expressions of doubt that we are in complete control of our destiny, much less our environment. "Technology Assessment" has been heralded as the means to better control the direct effects and side-effects of technologies on society and on our environment. The paper discusses:

- what is "technology assessment"
- what is its current status
- what can we expect from it
- how and who might accomplish successful "technology assessments"

FA3.1. Value of Quieting VTOL Aircraft, JOHN H. TINLEY.

Aircraft noise pollution is undesirable, yet quieting is not emphasized in VTOL aircraft designs due to imposed penalties. The value of and justification for quieting has eluded analysis, perhaps due to intrinsic complexities. A systems analysis methodology has recently been developed to value VTOL quieting for military applications. A helicopter noise reduction program, sponsored by ARPA, using the Army's OH-6A provides an actual basis for evaluating practical levels of quieting and the resulting tactical advantages. The methodology and generalized findings are presented in this paper and are extended to indicate that quieting might be justified for both military and civilian VTOL applications.

FA3.2. Scheduling Boundary Defenses to Minimize the Number of Penetrations, STEPHEN BALUT and GILBERT T. HOWARD.

We consider the problem of a defender guarding a boundary from attack by a fixed number of invaders who are approaching the boundary. His objective is to intercept

the maximum number of invaders before they cross the boundary. The defender is required to remain on the boundary. In the most general case considered, the invaders can move with any known motion and their speeds need not be the same. Weights may be also assigned to each invader to reflect the value to the defender of intercepting that invader. A dynamic programming solution suitable for hand calculation is given.

FA3.3. Attacking a Perishable Target System: A Dynamic Programming Approach, CLAYTON J. THOMAS and DAVID V. MASTRAN.

Frequently in warfare, a force is required to attack a perishable enemy target system—a target system where the targets are detected seemingly at random, and if not immediately attacked, will shortly escape from detection. A conflicting situation arises when an attack element detects a target of relatively low value and has to decide whether to expend his resources on that particular target or to wait for a more lucrative one, hoping one will be found. This paper provides a decision rule giving the least valued target that should be attacked as well as the resources that should be expended as a function of the attack element's remaining mission time.

FA3.4. Simplified Air Battle Based on Lanchester-Type Equations, ROY K. FRICK.

Classical Lanchester Theory is concerned with engaged forces which have the primary mission of destroying each other with little thought given to other objectives. However, the objectives of a particular mission can determine the firing doctrine employed which, in turn, will determine the form of the attrition equations which can lead to "laws of combat" which may differ from the linear or square laws of combat originally formulated by Lanchester. To illustrate how various forms of attrition equations, and "laws of combat" can emerge, several air battle situations are postulated, and a simplified analysis is made of each.

FA3.5. Approximate Localization Theorems for Optimal Facility Placement, A.J. GOLDMAN.

The problem is that of locating a flow-receiving facility in a region, so as to minimize the weighted sum of distances between sources and facility. It is shown here that if a subregion S both generates "sufficiently much" of the region's total flow, and admits entry via specified "gate" points without "too much" circuity, then (a) S contains at least one "near-optimal" location for the facility, and (b) no strictly optimal location can lie "too far" from S.

FA3.6. Possible and Likely Futures of Urban Transportation, FRANCISCO SAGASTI and RUSSELL L. ACKOFF.

Some of the effects of anticipated urban growth on urban transportation are examined in this paper. Current trends are analyzed in order to determine whether the current transportation system, with or without expansion, can handle future traffic loads at the 1960 level of congestion. We believe we show that it cannot do so and hence that fundamental changes will have to be made in the system. Alternative ways of changing urban transportation systems are then examined. In our view only one of these is capable of keeping urban congestion at an acceptable level, and it involves changes in the nature of the automobile and in its patterns of usage. This finding does not imply that urban transportation will move directly toward this solution. To the contrary, a great deal of trial and error is likely, and considerable amounts of money and effort will probably be wasted before the solution is generally adopted.

FA3.7. A System Approach for Congestion Control in a Street Network, CHUAN F. WANG.

The rapid urbanization of our society combined with inadequate supply of transportation facilities is continuing to worsen the scene of traffic congestion in our city streets. Since the expansion of street capacities is restricted by the scarcity of urban lands, the only alternative thus hinges on our ability to utilize the capacity of existing

street network to its utmost advantage. In this presentation, the system approach is used to examine the possibility of developing an area-wide control scheme for accomplishing this objective. A system problem of this nature is often characterized by an extremely large system structure with incomplete information. However, this complex problem may be brought within the comprehensible range if current system technologies are properly applied. A simple street network consisting of four intersections and twelve street links is used to illustrate the system procedure for the development of various control strategies.

FA3.8. Directions for Health System Reform, KAREN M. EISENSTADT.

Federal and state proposals to bring Medicaid costs down to a "reasonable" level have either contradicted the program's goals or focused on efficiency-type solutions. But the mismatch between health needs and resources is so great that efficiency-type solutions are inadequate. We need instead to radically overhaul medical care itself; particularly, shifting emphasis from in-hospital treatment to outpatient preventive care covering all citizens. This change is most important for achieving the fundamental goal of improving the nation's health. Systems analyses for health services reform cannot stop at the question of how to do better what we are already doing, but must also question whether we should be doing it at all. New York City experience with Medicaid and health systems analysis is used as an example.

FA3.9. Identifying the Unidentifiable– The Separation of Test and Assembly Errors within a Repair Facility, LEONARD ZACKS.

A repair facility model is structured so that the movement of an item within the facility is equivalent to a transition between two sets of states of a finite Markov chain. The underlying, unobservable transition probabilities of the Markov chain, which correspond to test and assembly errors and generate the observed transitions, are estimated using a minimal Chi-squared technique and it is shown that there exists only one transition matrix capable of generating the observed flows between the set of states. Consequently, in this special case, the identifiability problem is solvable and one is able to separate the test and assembly errors within the facility.

FA3.10. Regional Requirements for Hospital Services for Heart Disease Patients, ROBERT M. GURFIELD.

Planning traditionally denotes activities such as budgeting, site selection, architecture and floor layout, but there is growing acceptance for planning as a continuous process for increasing future options. In searching out options, hospital management must take greater cognizance of interactions within the contiguous geographic region, primarily with the population, other health services, and public programs. A hierarchy was developed to relate activities at individual institutions to planning at the region level. Region-based planning was applied to hospital services requirements for heart disease patients. A model of community dynamics computed the numbers of persons in the region needing particular services at one time. One example of the use of this model was the simulation of regional requirements for Coronary Care Unit Beds. The effects of changes in technology, social habits, population growth, and medical practice on the community's requirements for CCUs were investigated by sensitivity analysis. Projections of CCU bed requirements in the State of California through 1990 were made.

FA4.1. Bases for Design of an Information System: The Affinity and Utility to the Educational Planning Process,A.G. HOLZMAN.

Data bases exist in many forms in educational institutions today. The important objective, however, is to design a system which will translate raw data to useful information for the decision-maker in the academic field. The paper addresses itself to a micro-level information and planning structure for students and faculty in a school-

departmental level environment. The determination of a faculty load is an integral part of the total information system. A mathematical model is structured for planning the allocation of faculty resources, and a statistical decision theory model has been designed to assist in the acceptance/rejection decision on admissions to a school.

FA4.2. A Monte Carlo Technique for Sizing the Substitute Teacher Pool, JAMES BRUNO.

Providing substitute teachers in large school districts usually requires both an extensive organizational structure to coordinate substitute teacher demands with available supply and a large operating budget. This study demonstrates how Monte Carlo techniques might be utilized to determine the optimal size for a substitute teacher pool where optimum size is defined as (1) the size necessary to minimize cost, (2) the size required to maintain present substitute teacher service levels in the district, and (3) the size needed to financially break even with current practices. In addition to possible cost savings, the study shows how minority group involvement can be substantially increased, and how additional manpower for instructional support can be derived.

FA4.3. Development and Validation of a Micro-Level Forecasting Model for Student Enrollment, ISMAIL B. TURKSEN and ERROL D. PORTER.

This paper develops theoretically and validates empirically a model to forecast the number of students enrolled in the courses of a university by examining existing relationships such as pre-requisite structures of courses. The parameters of the model are estimated with data from the University of Toronto. Appropriate levels of aggregation of the data are determined and forecasts are compared with actual enrollments. The stochastic behaviour of external entries is studied in detail in order to determine the functional relationships of new admissions and the effects of their non-stationarity on the internal operations of a program. Differences between professional and arts programs are incorporated in the model. Error in the forecasts is estimated by studying the probabilistic fluctuations.

FA4.4. A Control Theory Approach to Small-College Administrative Decisions, W. GARY WAGNER and GEORGE B. WEATHERSBY.

The model presented in this paper applies the control theory formulation to a finite-horizon planning problem similar to those which are typically faced by small-college administrators. In particular, the problem is to determine an optimal sequence of faculty-hiring, student admissions, and physical plant construction decisions subject to budgetary constraints and in conformity with the observed dynamics of the system. The problem is naturally divided into three sub-problems: (1) a characterization of system dynamics, or simulation; (2) the development of a criterion function which adequately summarizes the administrators' goals; and (3) solution to the problem by optimizing the criterion function. This problem is formulated using typical data for California small colleges and is solved numerically for the optimal decision sequence.

FA4.5. On the Use of Large-Scale Simulation Models for University Planning, DAVID S.P. HOPKINS.

It is currently in vogue at many academic institutions to attempt to use large-scale deterministic models for making detailed predictions of future resource requirements. The purpose of this paper is two-fold: (1) to give a simple description of a typical university cost simulation model and (2) to raise some questions about its expense, accuracy, and usefulness as a tool for university management. In the author's experience, models of this type have several drawbacks that are not well understood by those who propose to use them. These drawbacks arise from the structure of the model, the way in which results are interpreted, and the magnitude of the underlying data collection task.

FA4.6. A Model for Analyzing Decision Making of Investment to Education, Y. COMAY, A. MELNIK, and M.A. POLLATSCHEK.

Dynamic programming is applied to the problem of optimal decision by an individual moving along the educational path. The stages represent several types of schools, and the transitions are partly controlled by the individual and partly determined by his abilities which are translated to the probability of success. A given population under study is divided into groups according to abilities and social status and the optimal path is calculated for every group. The output of the schooling system is given by the sum of the groups. It is also possible to investigate the influence of scholarships, preparatory courses, lowering the standards, etc., on the output.

FA4.7. Acceptable-Optimality Analysis of Qualitative and Quantitative Techniques in Education, ASHOK DAVE.

The use of qualitative and quantitative techniques in education, variously referred to as "systems analysis," "operations research," "management science," and "operations analysis," has virtually excluded the aspect of social acceptability as an essential consideration in design efforts. In other words, technological efficiency has been favored over human and societal needs and desires. This paper describes the construction of an interdisciplinary Acceptable-Optimality (A-O) model. The model incorporates both user-acceptance of the design, and solution-optimization for technological efficiency. A hypothetical example has been worked out to show the steps involved in the application of the model.

FA4.8. Models for School District Reorganization, DANIEL B. DAVIS.

This exploratory planning study develops and applies two decision-oriented mathematical programming models, an interactive and a heuristic, for reorganization of large urban school districts. The models maximize an objective function subject to political, social, and economic constraints, utilizing census tract data as the basic unit of analysis. The objective function maximized by these quantitative approaches is that of heterogeneity of racial composition, although these two models are general enough to be applied to other problems with different objectives and constraints. The heuristic model is similar to the linear programming approach used to redraw legislative district boundaries. These modern management techniques can be useful tools for educational administrators in large urban school systems who are trying to make their districts more efficient and more responsive to the educational needs of their constituents, especially for minority children.

FA4.9. Measuring Efficiency in Public Schools, RICHARD C. CARLSON and HENRY M. LEVIN.

A frontier production function is defined as the set of output coefficients which predicts maximum potential output for any set of inputs. A frontier function for schools is estimated by linear programming to find the marginal product coefficients for the schools which maximize output relative to input. This frontier production function is used to predict maximum potential output for the entire set of schools. The ratio of actual output to potential output is an efficiency index with cardinal properties. This efficiency index is compared to various characteristics of the schools, particularly the racial make-up of the student body. Separate efficiency indices are estimated for white and non-white students.

FA4.10. Relationships between Manpower Planning and Educational Planning, DONALD J. CLOUGH.

This paper deals with an evaluation of past and current manpower planning and educational planning models and their relevance for post-secondary educational planning in the Province of Ontario, Canada. Considering public demands and welfare, political institutions and processes, traditions of autonomous educational institutions, and persistence of customs and organizational forms, the paper draws some conclusions

regarding relationships between manpower and educational policies of government, priorities in planning activities, methodologies and models for planning, implementation of plans, requirements for information networks and organizations, and costs of planning. Some discussion deals with the bad practice of constructing models without theoretical underpinnings.

FA6.1. A Comparison of Three Computer-Aided Diagnostic Systems, DAVID H. GUSTAFSON, JOHN J. KESTLY, JOHN H. GREIST, and NORMAN N. JENSEN.

The research reported here develops and conducts an initial evaluation of a computer-aided diagnostic system that uses only subjective probabilities. Three diagnostic systems are compared; one using only subjective probabilities, one using actuarial probabilities developed in a standard fashion and one using actuarial probabilities based on a population partitioned into suspected hypothyroid and suspected hyperthyroid categories. An analysis of the data indicates that the subjective model's developmental cost and time required is much lower while it performs as well as either actuarial model.

FA6.2. Measures of Effectiveness for Medical Decisions, HARVEY WOLFE.

In recent years, considerable effort has been devoted to the structuring and to the solution of medical decision problems utilizing statistical decision theory. Because of the lack of development of measures of effectiveness by which to judge outcomes, extensions and applications of these techniques have been severly limited. Concepts of information theory and utility theory are applied to provide useful measures for evaluating decisions. Assumptions are made in order to develop logical theories for placing values on human lifetime and the disabilities associated with disease. It is the goal of this research to clarify in detail an initial conceptualization of measures of effectiveness by which medical decisions can be made.

FA6.3. Automating Judgmental Decision Making in Medicine, G. ANTHONY GORRY.

A decision theory model of the diagnosis and treatment of a serious medical condition, acute renal failure, has been implemented in an interactive computer program as part of a study of automated judgmental decision making. This program employs formal decision procedures and objective assessments of the likelihoods and preferences of experts. The program has proved very successful in duplicating the decisions of expert clinicians for the acute renal failure problem. This paper will discuss the underlying model and theoretical analysis of the decision problem and also give some experimental results obtained using the computer program. Also addressed is the question of the more general applicability of methods such as the ones used in this research.

FA6.4. Testing A Model for Predicting Physicians' Evaluations of Health Status, DON C. HOLLOWAY.

If a measure of health status was available, it might be used to predict medical decisions, to make medical decisions, or to evaluate medical decisions. This study develops for one disease, two models for predicting physicians' evaluations of patients' health status. One model treats the criteria for evaluating health status as additive; the other combines criteria for non-additively. The latter model is at least as predictive as the additive model, and is significantly more predictive for two of the six physicians studied. The predicted evaluations from the non-additive model are validated for use as a measure of health status: length of stay, type of medication administered, the predicted changes in patients' health status from the initial medical exam to the follow-up exam with statements written by the attending physician in the medical record. In both cases, the relationships are as expected from a measure of health status.

FA6.5. To Grant or Not to Grant: The Decision-Making Process for Health Services Applications, JOHN R. HALL, SR.

The applicant who seeks grant support faces a decision-making process designed to establish the scientific merit and program relevance of his proposed project.

The strengths and weaknesses of such proposals will be discussed from the hindsight of three years of experience in the process.

FP3.1. Mid-Air Collisions in Future Air Traffic Environments, KENNETH E. WILLIS.

The majority of airplane accidents today occur during landing and takeoff, with relatively few mid-air collisions. However, as air traffic densities around the large hubs increase, the relative hazard due to mid-air collision must increase. A model was developed to predict the expected frequency of mid-air collision between VFR-VFR and VFR-IFR aircraft. Historical data for the Los Angeles basin was used to validate the model, and the model was then used to project the expected number of mid-air collisions for the future. The terminal air traffic control system is briefly described, and the way in which the system could be expanded or modified to alleviate the potential problem is discussed.

FP3.2. Airline Fleet Planning Model, J.W. STROUP and D.P. SHUBE.

The Airline Fleet Planning Model is a tool designed to assist in the development of a fleet plan for a multi-year period in the future. The approach uses linear programming to allocate aircraft to given routes subject to flight frequency restrictions and aircraft operational limits. By the use of appropriate constraints the model takes into account: changing passenger demand, company financial position, predetermined plans for acquiring and retiring aircraft, initial fleet composition, and introduction dates and production rates of new aircraft. Optimization of the solution is obtained by minimizing either operating costs, total inventory valuation, new inventory costs, or operating costs plus cost of capital invested in the fleet. Results include types and quantities of aircraft to be bought or retired, the timing of these changes, and a summary of aircraft operational data.

FP3.3. A Model for Comparing Driver Improvement Programs, JOSEPH FEREIRA, Jr.

A model for comparing alternative driver improvement programs is developed. The cumulative effect over several years of using various strategies for selecting drivers for training is measured in terms of the number of accidents avoided, the number of drivers trained, and the extent to which the strategies select the worst drivers. The future accident involvement records of groups of drivers with similar accident history are predicted using a Bayesian updating of accident likelihood estimates based on a compound Poisson accident model. The accuracy of this method is tested using six-year accident data for a sample of California drivers.

FP3.4. The Fire Engine Relocation Problem: Formulation and Algorithm, WARREN E. WALKER and PETER J. KOLESAR.

When a large fire, or several small fires, is being fought in one area of a city, the fire houses of the working fire engines are left empty, resulting in a sharp degradation in the fire protection afforded the surrounding area. Traditional practice is to relocate engines into some of the empty houses. This paper presents a mathematical formulation which determines when relocations should be made, the empty houses to be filled, and the fire companies to be relocated. An algorithm is presented which is suitable for implementation in a real time, computer-based, command and control system. The application of the algorithm to some actual fire scenarios are presented.

FP3.5. Optimal Resource Allocation in Family Planning Services Delivery, WARREN H. HAUSMAN and PHILLIPPE A. NAERT.

A stationary Markov chain model relating to the delivery of family planning services has been formulated by Urban. The model represents the probabilistic movement of women through states representing no family planning services available, pregnant, delivered and interviewed by a family planning agency, delivered and not interviewed, etc. This paper extends Urban's work to analyze resource allocation decisions. Both steady-state and transient goals are considered, however, the transient-goal case seems to be more important, more applicable, and more representative of the goals of those involved with

family planning. The paper concludes with the evaluation of alternative model formulations and solution techniques for the transient-goal case.

FP3.7. Some Effects of Food Products Packaging on Solid Waste Disposal Systems, RONALD A. NELSON.

Developments in the food products packaging industry over the past several years are evaluated in terms of (1) their contribution to the amount of solid wastes a household throws away, (2) the additional costs to the consumer, (3) the benefits enjoyed by the consumer and the food products industry (4) the additional cost to local, state, and Federal governments, and (5) the additional depletion of our supply of natural resources. Some alternative methods of packaging are considered according to their potential contributions to: (1) reducing the amount of solid wastes, (2) reducing the cost to local, state, and Federal governments, and (3) reducing the depletion of our natural resources, without increasing the costs to the consumer or measurably decreasing the benefits to the consumer and the food products industry.

FP3.8. The Cost-Benefits of Econometric Studies of Marketing Systems, P.C. BURGER and R.L. SCHULTZ.

This paper views the firm and the consumer as an interactive system of mechanisms. The means of collecting data, estimating the parameters of the system model and testing the system for identification of effects is discussed. The costs of testing and data collection are stated. The payoffs to the firm are illustrated and questions of optimality are discussed. An example of such an analysis sponsored by one of the nation's largest air carriers is used as the primary illustration of the process and its payouts. A small simulation has been created based on the system equations describing the airline and its customers. A brief discussion of recent similar studies is also included.

FP3.9. An Optimum Student Flow Model for Large-Scale Higher Education Systems, DAVID A. SANDELL and WILLIAM A. WALLACE.

The underlying philosophy of this model is to optimally match students with educational resources over a finite planning period so as to minimize the costed disparity of mismatch. This approach is in contrast to current enrollment projection models which implicitly assume the availability of resources justifiable by projected enrollment. The decision variables are elements of Markovian transition matrices which describe student flow throughout the education system. The dynamic linear programming formulation has a decomposable block staircase structure. Yearly enrollment vectors and saturation coefficients of the various states of the system are additional outputs of the model, useful as measures of overcrowding or under-utilization of facilities. An application was made to the State University of New York system.

FP3.10. A New Approach For Solving Optimization Problems, V.K. CHICHINADZE, N.I. JIBLADZE, and R.G. VACHNADZE.

Many problems require finding a global optimum, a task often complicated by multiple extrema and break points. Such problems may be further complicated by uncertainty. This paper develops a new approach, based on the psi-transformation, which can be used for solving complex optimization problems with either complete or incomplete information. Solutions to some practical problems of optimal planning are obtained.

FP4.1. Multi-Modal Transportation Model as a Tool for Regional Planning, MICHAEL JAY ROBERTS.

This paper documents the workings of the multi-modal transportation model (MMTM). This model simulates the interaction of multiple transportation operators as they compete for patronage. The basic components of the MMTM are a demand and modal split model and multiple supply models. These are operated contrapuntally until a simultaneous equilibrium is reached between operators and users. In addition to a description of the MMTM, some practical uses of the model are discussed. The model system has

been used by the Depart of Transportation to provide information for planning future transportation facilities for the Northeast Corridor. Other possible uses are also presented and discussed.

FP4.2. A Personal Epilogue on the Northeast Corridor Transportation Project: A Pyrrhic Lesson for the Profession, JOHN L. DONALDSON.

For over half a decade, operations researchers attempted to solve the problems of transportation in the Northeast Corridor. The first half of this presentation reviews briefly the evolution of the project noting major research tasks undertaken in the course of its development. These tasks are discussed from the perspective of how they ultimately contributed to the outcome of the project. The second part of the presentation describes the project's results with respect to the prospects for high-speed ground transport in the Northeast Corridor, outlines the methods used to obtain these results, and finally evaluates the adequacy of the methodology.

FP4.3. The Usefulness of Alternative Techniques for Analyzing Transportation Issues, MELVYN CHESLOW.

Analytical techniques, such as the ones given previously in this session, vary in the level of aggregation and amount of detail. In a large scale problem, such as the study of regional transportation policy, many aspects of the complex interrelationships must be analyzed. The benefits from using a variety of techniques are explored. An evaluation procedure which can use the results from the various analyses is also presented. This technique has been structured to weigh and trade off the concerns of members of broad interest groups so that it can assist decision making in a real world situation.

FP4.4. Cost-Effectiveness Analysis of Incremental Railroad Improvements, STEVEN DITMEYER and LINDA WILSON.

A great deal of attention was given in the Northeast Corridor Study to improvements to the existing railroad line between Washington and Boston because costs projected for these improvements were substantially lower than for alternative new modes. Because of the large number of potential improvements to the line, incremental improvements were simulated, using a mathematical model whose output provided a detailed history of all rail movements on the line during the simulated time period. Effects of new or different rail structures and of different levels of train service were analyzed, permitting changes to be made to the engineering design criteria, if necessary.

FP5.1. Decision Making: The Target of Systems Science in Social Programs, ARTHUR SPINDLER.

Social programs of the United States are in a nascent period of great change as social problems worsen. The search for improvement is under way and critical decisions need to be made about the new directions of these programs. System sciences can be applied to better advantage if there is a clearer understanding of the factors which concern decision making in these programs. This presentation identifies the decision makers, discusses their attitudes, the environment of decision making, the issues and problems which must be resolved, and the objective/subjective bases for decision making. A set of objective criteria for the decision-making process is suggested which is susceptible to systems development and analysis.

FP5.2. Urban System Decision Making with Multiple Consequences, LOUIS SLADE, JOSEPH L. SCHOFER, and MARTIN WACHS.

The problem of decision making among urban system alternatives which have multiple consequences is viewed in the context of a hyperspace. The dimensions of the space are defined by the consequences and the alternatives are represented by vectors in the space. The overall value or worth of an alternative is defined by a function of the dimensions of the space and therefore the utility function defines parallel hypersurfaces in that space. This approach to the evaluation of complex urban systems is considered to be extremely flexible, and directly applicable to many problems of urban systems evaluation. This paper includes discussion of: relationships between planning objectives and the definition of the hyperspace; the measurement and representation of goal achievement;

the definition of utility hypersurfaces; analysis of the hyperspace with respect to actual urban decision-making problems; and study of the sensitivity of the approach to variations in risk and uncertainty.

FP5.3. Resource Allocation Models Applied to Fire Departments, ERNST NILSSON, DONALD COLVER, and RICHARD KU.

Fire departments have been largely untouched by new management techniques and applications of resource allocation models. This paper reports on the definition of resource allocation problems, development of models and their implementation in the greater San Jose area. Specifically, several fire station location models, queuing models and a simulation model will be discussed.

FP5.4. Operations Research and Urban Education, YING C. CHUANG.

Modern urban educational systems are becoming more complex. This complex educational system, functioning in a highly integrated and interdependent manner to achieve an overall performance, is a critical problem. During recent years, the methods of operations research have been increasingly applied to urban systems in general and to urban education in particular. This paper presents the application of O.R. to urban educational systems in the categories of educational research, educational evaluation, educational planning, educational training, design of instructional systems and others.

FP5.5. Methods for Allocating Urban Emergency Units, JAN M. CHAIKEN and RICHARD C. LARSON.

Urban police and fire departments, emergency ambulance services, and similar urban emergency service systems comprise an important class of governmental service agencies that until recently has not benefited from systematic analysis of operational problems. These systems operate in a complicated environment that includes temporally and spatially varying demand patterns, both explicit and implicit administrative, legal, and political constraints, and often ill-defined mixtures of objectives. This paper reviews those operational problems of these agencies which are related to the deployment of their vehicles and reports current progress on the quantitative solution to these problems.

FP6.1. Operations Research and Systems Engineering: Application in Comprehensive Health Planning, RICHARD F. JACOBSEN.

The potential application of Operations Research in Comprehensive Health Planning has been recognized and acknowledged. However, financial constraints and the absence of technical expertise in CHP have prevented any large-scale realization of this potential. Possible applications include the use of gravity models for planning facilities location; queueing theory in planning manpower requirements subject to quantity and quality constraints of health services; systems simulation in analyzing alternative methods of medical care financing; and PPBS in programming the implementation of comprehensive health plans.

FP6.2. The Use of O.R. Techniques in Regional Medical Programs, DON TRANTOW.

The Regional Medical Program's orientation has changed from a heart, cancer, stroke project funding mechanism to the development of programs designed to increase the effectiveness and efficiency of community health services. As a result, within this new mission, the Regional Medical Programs must assess community health care needs and then design a strategy to meet those needs. As a result, much of the emphasis has shifted from scientific review of specific projects to a management approach to the development of community health care programs. This, of course, cannot be achieved effectively without the expeditious use of management tools with Operations Research being one of the most important elements. O.R. techniques will, therefore, play a major role in the future Regional Medical Programs activities.

FP6.3. Systems Engineering Applications in the Kaiser-Permanente Program, MORRIS F. COLLEN.

The Kaiser-Permanente Medical Care Program, through a system of eleven hospitals and fifteen clinics, provides prepaid, comprehensive medical care to almost one

million people in the San Francisco Bay area. Its goal is to provide good quality medical care at a reasonable cost. Its basic concepts of organization of health care and its basic principles of operation have been well defined. To achieve these, operations research, systems analysis, industrial and systems engineering methods have been applied to the overall health service system and to many subsystem units. Examples of applying such methods to planning, testing and evaluating alternative methods for providing medical care within the Kaiser-Permanente programs are described

FP6.4. Operations Research and Planning in the Indian Health Service, E.S. RABEAU.

The Indian Health Service, a division of the U. S. Public Health Service, is responsible for the delivery of comprehensive health services to approximately 500,000 American Indians and Alaskan Native people. In 1966, the Service established the Health Program Systems Center as a research and development organization to investigate the utilization of the methodology of operations research and systems analysis to improve the delivery of health services. Among the specific applications to be discussed are a complete, remote access, computer-based medical information system serving some 10,000 patients through four clinics on the Papago Reservation in Southern Arizona, and an outpatient clinic data collection and simulation package used to study patient flow dynamics and staffing patterns.

FP7.1. Allocation of Resources for Barrier Patrol Missions, EDWARD R. JAHN.

The problem of allocating resources is a very general one which is often handled by various mathematical programming techniques. This paper treats the allocation of several types of assets to patrol sectors and subsectors within each sector. Integer constraints are placed on the number of assets of each type in each sector. Using a practical example, it is shown that a rounded-off solution of the continuous linear programming formulation will in most practical cases be a very good sub-optimal solution to the integer problem?

FP7.2. The Evolution of Game Theory, JOSEPH B. JONES.

This paper traces the evolution of game theory since inception. Emphasis is placed on the relation of game theory, information, and organization theory.

FP7.3. Application of Linear Programming to Optimal Product/Market Mixture for Olsen Brothers, DONALD REIFER.

This paper describes how an interactive manager-computer system can help a large egg producing and distribution company overcome its product/market allocation problem. The interactive system produces an integrated statistical/judgmental data base which is optimized by linear programming. The result of the analysis is a forecast which outputs a variety of reports that management can use and understand.

FP7.4. A System for Controlling Major Milestone Accomplishment in Project Planning, JOHN R. SINGRIN.

This paper presents a generalized system for scheduling and regulating objectives in project planning in the context of milestones. The procedure is applied to a joint national conference on major systems.

FP7.5. A Simulation Model of Decision Making in a Management Game, WILLIAM C. FARRELL.

A cognitive process simulation model of a person playing a business game is developed, based on postulates for an information processing theory of human problem solving. It presents a partial qualitative description of the thought processes induced by a business game. It models the strategies used by the one subject studied, and rules he used for switching between strategies. Two new methodological variations are used: protocols are taken from the subject as he learns the game rules, in order to determine his initial concept of the problem; decision tables are used to aid in the protocol analysis.

Abstracts

SIMULTANEOUS SESSIONS

SS1A.1 Long Range Student Scheduling Using Pert, THOMAS B. BAIRD and WILLIAM ARBOGAST.

This paper presents a series of procedures for performing student advising and scheduling from the freshman year through graduation via the computer. The procedures are broken into three phases. Phase I applies "PERT" to techniques to assure prerequisites, ordering, etc., after the student, with his advisor, has selected desired courses. "Load leveling" is utilized in creating the necessary schedules. After adjustments have been made, Phase II verifies the feasibility of the final plan, and records the schedules in real time. Course summaries are created for departmental planning. Phase III allows the registrar to preprint enrollment cards. Computer programs are available for all three phases.

SS1A.2 Some Manpower Planning Models Based on Levels of Educational Attainment, WARREN L. BALINSKY.

A number of manpower planning models are developed and optimized. The models are dynamic feed-forward models and treat people as the only flow variable. The flow originates by considering a particular population of eligible persons and then traces them through the educational and economic sectors of the model. The flow is driven by selecting the optimal number of entrants into the educational (training) program each period. The objective function is composed of educational and manpower "inventory" costs. The manpower costs are for having an undersupply or oversupply of trained manpower and can be related to unemployment, educational or other societal costs.

SS1A.3 The Creation of New Agricultural Communities to Stem the Flow of Individuals to Urban Areas, JERRY BANKS and JOHN C. DeVITTO.

This paper presents the results of an investigation of the feasibility of conducting labor-intensive farming subject to a controlled environment, to decrease the flow of individuals from the rural to urban areas. A unique feature of this proposal is that individual low-income farmers will be responsible for a five acre tract of land, and receive training and instruction from a managerial super-structure. The technical problems which must be solved include crop rotation, scheduling of agricultural activities, and resource allocation. The techniques and methods of operations research and systems engineering are employed to overcome these technical problems subject to sociological considerations.

SS1A.4 The Study of the Traffic Intersection through Simulation, J. WESLEY BARNES and ROBERT M. CRISP, JR.

The analytical complexity of most automobile traffic intersections strongly directs the researcher to simulation as his tool of analysis. This tool, through the General

Purpose Systems Simulation language (GPSS), was used in a recent investigation of seven different intersections. On the basis of a comprehensive literature search, the authors feel that the simulation models reflect, as nearly as is presently possible, the "real-life" situations. This paper, an outgrowth of that investigation, includes discussions of:

(1) Basic assumptions of the models,
(2) empirical probability distributions employed,
(3) practical applications, with results for a selected objective function, and
(4) conclusions and recommendations for further research.

SS1A.5 Development and Growth of Urban Areas Caused by New Transportation Systems, HENRY L. BEENHAKKER.

Elements of urban development that could be affected by a different transportation system are real estate values, availability of employment, air pollution, urban design and aesthetics, education, urban and suburban residential housing patterns, access to cultural and recreational facilities, industrial and commercial location, differential effects, transitional effects and inter-urban transportation. How does one incorporate the impact of changes in these elements on future demand for urban transportation, in the single projection of the growth rate of urban areas as a whole?

SS1A.6 A Computerized Model for Analyzing School District Financial Problems, A. J. BENJAMIN and R. JOHN PREVOST.

A computerized financial model of a large school district has been developed which permits public administrators to calculate the economic impact of alternative programs and policies over a ten year period. The model is designed around nine input information libraries which serve as a repository for data pertaining to (1) school district educational and economic characteristics and (2) state and Federal funded educational programs. Over forty algorithms incorporate the input data for calculating various revenue and expenditure accounts. The model outputs budget forecasts in three levels of detail. To date, numerous scenarios have been successfully run, utilizing data from a local school district. The model is currently in use by the City of San Antonio, Texas.

SS1A.7 A Pupil Performance Measure for Criterion-Referenced Instructional Program, RONALD BESEL.

Criterion referenced instructional programs are well suited for operational analysis, since goals are precisely stated in terms of behavioral objectives. A Bayesian mastery-learning test model is used to estimate the probability that a student is in the mastery state for each program goal. Targeted dates for the achievement of program goals are selected. The performance measure considers three factors: the relative value of goals; the assessment date (relative to targeted date); and the probabilities of mastery. Greater incremental value is attributed to getting students up to targeted achievement than to achieving mastery "ahead of schedule."

SS1A.8 An Urban Systems Study for Melbourne, JOHN F. BROTCHIE, RON SHARPE, A. RAY TOAKLEY, and JOHN W. DICKEY.

This paper deals with an urban systems study for the future development of Melbourne, a city of 2.3 million people which is expected to increase to 5 million by the year 2000. The aim of the study is to apply a general econometric planning model recently developed to optimize the growth pattern of future development on a comprehensive basis of all quantifiable benefits and costs. The general model allocates activities to spaces and resources to activities both in space and time. The benefits and costs include those of interaction between activities and between activities and the environment. Non-quantifiable benefits and costs are also allowed for in sensitivity analysis techniques. The model has been specialized to urban planning by inclusion of behavioral submodels for route selection, destination selection, and proximity effects. It has been calibrated to Melbourne data in a cooperative effort between the planning authority and the research team, and information for urban planning decisions is now being produced.

SS1A.9 Measuring Urban Performance, ALBERT BROWN and RONALD F. KIRBY.

The concept of urban performance is introduced and discussed, and specific quantitative performance measures are formulated and their values calculated using observed urban data. The sensitivity of these performance measures to the distribution of land activity and the nature of the transportation facilities in an urban area is investigated, and the influence of alternative planning policies on the latter factors, and hence the urban performance measures, is discussed. Urban data requirements for the calculation of the urban performance measures are specified, together with the data and procedures for estimating the effect of alternative planning policies on the performance of an urban area.

SS1A.10. Crime Prediction Modeling, ROBERT G. CHAMBERLAIN.

In 1969, the Los Angeles Police Department conducted an operational experiment in the use of helicopters as patrol vehicles. JPL assisted the LAPD in the evaluation of effectiveness. A key element in the evaluation procedure that was developed was prediction of the amounts of crime that would have occurred if the helicopters had not been present. This report discusses the technical and philosophical problems of crime prediction and presents a description and evaluation of the methodical approach used. A bonus, the development of a modification to the multiple exponential smoothing technique which eliminates the need for *a priori* estimates of the model parameters, is contained in an appendix.

SS1A.11. On An Optimal Allocation of Pupils with A Public School System Operating Under A Racial Balance Constraint, WILLIAM E. CULLISON.

School boards in cities which are using busing as a means of school desegregation face considerable hostility, even when they are ordered to do so by the court. The basic problem faced by the school board is how to balance the schools racially while minimizing the disutility accruing to the community. By utilizing constrained maximization and basic economic principles of decision-making and choice criteria, an optimal solution is readily available. This approach to the desegregation problem is detailed.

SS1A.12. Analysis of Housing Decay, ANDREW F. DAUGHETY.

In view of the mounting crisis occuring in our urban centers due to decaying housing, this paper examines the problem of decay through the analysis of housing code enforcement manpower deployment. The paper concentrates on violation severity, different forms of code compliance and the development of a model for both inspector deployment and the evaluation of the effectiveness of existing housing codes.

SS1A.13. Actors, Factors and Urban Performance Indicators, JOHN W. DICKEY and ROBERT C. STUART.

A survey was conducted covering 152 urban transportation decisions. The "actors" in the decision processes were identified. They included urban planners, transportation planners, traffic engineers, urban renewal administrators, architects, mayors, etc. (28 types in all). "Factors"—value considerations—entering into the decisions were also identified. The decisions were analyzed for (a) associations of certain factors with certain actors, and (b) the urban performance (social) indicators that would appear to be most important to each set of actors. Both quantitative and qualitative indicators are considered.

SS1A.14. The Social Feasibility of Computer-Aided Instruction, EDWIN DUPNICK.

It is the purpose of this paper to develop a measure of the social feasibility of computer-aided instruction (CAI). Social feasibility places emphasis on the effect of CAI on the overall system of society (not necessarily national) rather than focusing attention on just one component of society—the educational process. This measure of social

feasibility, called collective utility, represents an effort to classify some of the issues and problems involved in deciding to implement or extend the use of CAI. The model developed in this paper discusses how CAI can be economically integrated with other resources and components of the educational system, and attempts to deduce the social implications of CAI. Many decisions concerning CAI may be stillborn because the decision makers failed to consider their probable effect on such diverse factors as computer sales and human satisfaction. Collective utility is sufficiently flexible to include these factors in their proper perspective of uncertainty.

SS1A.15. Teaching Urban Systems—A Large Scale Project Approach, PAUL GRAY.

A course in urban systems offered annually at Stanford involves 100-150 undergraduate and graduate students who examine a major urban problem for 2 quarters. In 1970 the problem was the future of San Francisco over the next 10 years; in 1971 the revitalization of the Mission, a Latino district. By working in task groups of 8-10, by hearing and talking with both establishment and community leaders, by gathering data and evaluating proposed solutions, the students develop understanding of the problem and synthesize new alternatives. A major report of findings and recommendations is published as the course output.

SS1A.16. School Vandalism. A National Dilemma, BERNARD GREENBERG.

In recent years with the increase in racial tensions, violence and student activism throughout the nation, the rate of incidents in the schools has reached alarming proportions. The severity of the economic loss is clearly reflected in the actions of the insurance industry. Research to date has failed to establish a generalized set of antivandalism techniques, technological and sociological, that can be universally applied with predictable results. Although much literature is available on juvenile delinquency and its relation to the criminal justice system, only fragmentary research has been reported with respect to delinquency and the school. The inference is that the school itself has a vital role in the community; consequently, its physical integrity must be protected and its contribution to the community's needs must be enhanced.

SS1A.17. Systems Analysis of Effectiveness of Techniques in Prevention of Chicago Transit Agency Bus Robberies, LONNIE E. HAEFNER.

This paper presents a conceptual attack on the problem of enforcement deterrents on bus robbery activities prior to the installation of exact change fareboxes in the Chicago Metropolitan Area. It focuses on a rather narrow definition of utility concepts of the criminal, and the enforcement and transit user entities. Through incorporation of this utility structure into a game theoretic approach, a foundation for studying the problem in a theoretical mathematical programming context of the allocation of enforcement deterrence activities is made. A sensitivity analysis of potential tactics within the above allocation approach is discussed, in conjunction with the current level of overall criminal activity in the city.

SS1A.18. Experiments With An Interactive Search Procedure for Changing Transportation to Guide Urban Growth, R. A. HALL and J. W. DICKEY.

In attempting to guide growth in a given urban area, the planner often cannot devise neat objectives and tradeoffs because of the number and obscurity of the objectives involved. In this study, a large array of land use, travel, and transportation system capital cost consequences predicted to occur because of certain transportation system alterations are presented to the decision-maker(s). He reacts by assigning a subjective score between zero and one hundred to the set of consequences. These and other scores then are employed as objective function values in a search routine to determine the changes in the control variables (the transportation system) that are predicted (via a set of models) to bring about a set of consequences having the highest score. Experiments with this interactive search procedure seem to indicate its feasibility for actual application.

SS1A.19. Optimal Selection of University Course Offerings, JAMES A. HEINEN and EDWIN C. FOUDRIAT.

At most medium-sized universities, decisions as to which courses and how many sections of each should be offered in a given semester are made at the departmental level, and are generally based on little or no quantitative information. An automatic (computer) course selection procedure is described which makes such decisions in an optimal fashion to satisfy the individual needs of as many students as possible while operating within the constraints of available faculty and maintenance of desirable section loading. A modified critical path technique is employed in studying each student's program and in determining a priority list of courses which he should take. This procedure will aid in making the most efficient use of limited university resources, and can eventually be coordinated with automated class scheduling, space assignment, and registration.

SS1A.20. Partitioning of Police Districts Into Optimal Patrol Beats Using A Political Districting Algorithm; Model Design and Validation, NELSON B. HELLER, ROBERT E. MARKLAND, and JAMES A. BROCKELMEYER.

One very challenging and complex aspect of police resource allocation concerns the partitioning of police districts into patrol beats in such a way that police effectiveness is maximized, that beats are convenient to patrol, and that beats contain approximately equal shares of the workload. This paper summarizes the results of a study in which a computerized political districting algorithm has been employed to design police patrol beats, using input data provided by the St. Louis Metropolitan Police Department. The computerized model has been used to derive patrol beats which are optimally defined in terms of being compact, contiguous, and having a proportional amount of geographical area, crimeload, and workload. The model output is validated by comparing the computer designed patrol beats to the patrol beats which are presently computed manually, and by critically evaluating the computer designed patrol beats with respect to conflicts concerning street layouts, traffic patterns, and ease of patrol.

SS1A.21. An Intercity Comparison of the Cost of Police Services, RICHARD B. HOFFMAN.

In the development of a theory of optimal control for deviant behavior, particularly those forms of behavior which are legally proscribed (i.e., criminal activities), it is necessary to determine the cost of both this behavior and the cost of attempts to control this behavior. This paper investigates a portion of this latter aspect. An analysis of cost behavior as it relates to environmental variables, (e.g., density and population) can be a key to developing measures of relative effectiveness between cities. In many ways, the techniques used in estimating relationships for the costing of public services are similar to those used in military applications. The primary differences relate to the need to analyze the effects which are exogenous to the policing system but endogenous to the society which the policing system serves. Hence there is a need to adjust for various factors which may be proxies for social control (e.g., population and density). The analysis of relative cost of providing police services using adjusted and unadjusted data is then compared to indicate the effect of these exogenous factors upon the variations in policing cost.

SS1A.22. The Servomechanistic Aspects of Congestion Problems, PHILIP HUANG.

In applying systems analysis to congestion problems, the unified concept of impulse response is employed to obtain the expressions for state and output with inhomogeneous Poisson input and time varying mean service time in the $M/G/\infty$ system. Statistical independence is established for the same Consideration is given to the properties of the $M/G/\infty$ system, of the cascaded system, and of the system of general structure. This approach establishes the relationship between $M/G/\infty$ systems in congestion and transfer functions in linear system theory.

The control problem is reduced to linear deterministic form by approximating an on-off controller with an analog controller and by simplifying the performance index. It is found that the use of a linear deterministic control is very effective in

controlling stochastic systems. The effectiveness is demonstrated by simulation on a two stage service system.

From the approach shown in this paper, system identification and control become possible regardless of the complexity of the system.

SS1A.23. A Comprehensive Elementary and Secondary Education System (CEASES), WALTER LEE HUGHEY.

In recent years public demands for accountability have necessitated evaluation of the educational process against the expenditure of tax dollars. The professional response made by the Atlanta Public Schools was in funding the Comprehensive Instructional Program (CIP), designed to improve instruction in all areas of elementary curriculum. This program made highly visible the need for a management information system (MIS) which would permit continuous assessment of pupil progress and teacher performance. From this need evolved the concept of a Comprehensive Elementary and Secondary Education System (CEASES) which provided the required MIS in the context of a changing process of public education.

SS1A.24. Experience In Working Urban Problems: Some Observations, J. P. IGNIZIO, R. M. WYSKIDA, and R. E. SHANNON.

The University of Alabama in Huntsville, Industrial and Systems Engineering Department, has been engaged in the field of urban problems since 1968. In this paper we present a discussion of some of the often surprising experiences we have encountered in this work. Specifically, we list various problem areas (and their solutions) in our efforts with the City of Huntsville, the Model Cities Agency, and the Unemployment Office We believe that, by sharing our experiences in actually working these problems and implementing the solutions, others may benefit.

SS1A.25. Uncertainties and Electricity Planning, PRAFULLA JOGLEKAR.

The subject of long range regional electricity planning has received fairly extensive consideration in the literature. Unfortunately, almost all of the studies proceed with given forecasts of demand. This paper points out the high degree of sensitivity of the GNP of a region to the forecasting errors. Using the simple News Boy Model the paper concludes that the use of an optimistic forecast is highly preferable.

India is used as a case study. The multi-organization involvement and consequent complexities of the planning process are also discussed. The concepts find direct relevance in many other areas of public planning.

SS1A.26. Problems in Urban Transportation Planning, THOMAS M. JOHNSTON.

Throughout the United States the so-called "downtown" district in many cities is in serious trouble. Urban mass transit systems of most municipalities have not developed adequately in response to changing conditions. Often elegant new roads attract more traffic than the recently increased capacity can accommodate—especially at the terminus of new super highways, i.e., the cities. Accordingly, new highway plans must be properly coordinated with plans for improvements in other forms of transportation and must be consistent with other urban land use and development plans. To accomplish this, most towns in excess of 50,000 people will need a comprehensive transportation planning process which, in turn, will require substantial data, inventories, analysis, and a methodology for continuous updating of such data.

SS1A.27. Humanistic Technology: A Contradiction in Terms?, DAVID W. KEAN.

It is often said nowadays that our burgeoning technology and the environmental crisis will necessitate some profound changes in communal attitudes if we are to survive, but very little is said about what, precisely, this means,—which attitudinal changes will yield which environmental reliefs. Yet it is important to be specific in this

area, so that the tradeoffs can actually be considered by our decision makers and the general public.

This paper will discuss one such question,—the application of electronic computation to the urban transportation problem. Several alternatives are examined, and it is concluded that the maximum payoff is to be had by matching drivers of private vehicles who are contemplating trips with those needing rides, the objective being to fill a few of the empty seats that add up to 2¼ *trillion* passenger miles per year of excess capacity for the private automobile. Even a modest success in this endeavor would yield impressive returns in terms of highways not built and pollution not created, not to mention direct dollar savings, but the price, of course, is a change in attitudes about sharing rides downtown with strangers. It is suggested that tax incentives can hasten this change.

SS1A.28. A Survey of Approaches to the Facility Location Problem, BASHEER M. KHUMAWALA and D. CLAY WHYBARK.

Recent work on the problem of locating facilities from which goods or services are distributed, such as fire stations, consumer goods warehouses, post offices, branch banks, medical clinics, manufacturing plants, etc., has led to several promising solution approaches. This paper presents a survey of several such approaches including simulation, heuristic methods, linear and mixed integer programming, and branch and bound. Computational experience with the most promising approaches on large practical problems is also discussed.

SS1A.29. The Zodiac Cipher: A Triple Overlay, BARTON S. LOCKWOOD.

After giving a brief introduction to the Zodiac case, the paper will highlight motivation, methods and cryptanalytic results of voluntary work for the San Francisco Police. Included will be: 1) the analysis, methods and mathematics used in the Zodiac Crypto-system determination; 2) a brief discussion of system types available (Transposition and Substitution), and sub-types used; 3) parallel or similar systems analysis (Julius Caesar, Pig-Pen, Tic-Tac-Toe and Playfair Ciphers); 4) innovations (Fortran IV commands, Spanish, Algebraic "shift logic"), solutions and conclusions. Emphasis will be given to advancing technology and the need to use highly trained Aerospace technical personnel and resources in Police Investigative work.

SS1A.30. Cost-Effectiveness Evaluation of Freeway Design Alternatives, ADOLF D. MAY.

A freeway traffic evaluation model has been developed and applied in the evaluation design alternatives. The input for the model consists of freeway route characteristics and origin-destination demand patterns. The model processes this information through the use of queueing and non-queueing sub-models and results in the calculation of the total passenger time expended for a given traffic demand over a given design freeway.

The measure of effectiveness, total passenger time, can be determined from the model by various design alternatives. The annual cost of the various design alternatives are determined and combined with the measures of effectiveness to determine the cost effectiveness of each design alternative. An example problem is contained in the paper which results in a cost-effectiveness curve of the stage development of the design alternatives.

SS1A.31. The Anticipation of Requirements for Police Assistance, ELDON S. MILLER.

A police officer who thoroughly knows the area and people covered in his patrol is more effective than one who does not have this familiarity. Such familiarity is usually acquired individually, highly subjective, not usually transferred in any systematic manner to other officers and rarely is given full value in the development of police policy.

The Police Response Early Warning System (PREWARNS) is a systems development project in University City, Missouri which will match police dispatch and

complaint files with housing and population census descriptions of police districts and blocks. Records from the city's occupancy permit program will permit continual update of these descriptions. The matching of these source data will provide information to overcome the shortcomings identified above.

SS1A.32. Models for Fire Department Resource Allocation, PHILLIP S MITCHELL.
General optimization models for the simultaneous selection of the number and location of fire engines and stations are developed. Heuristic methods for solution are discussed and the basic model is extended to include multiple engine response, distance and budget constraints and an extended planning horizon. Operational problems such as the closing or relocation of existing stations are considered.

SS1A.33. A Resource Allocation Model for the Educational Sector, JOHN M. MULVEY.
An abundant and ready source of applications for Operations Research is the educational sector. Hundreds of thousands of students and teachers are scheduled into thousands of classrooms several times each year. Computers have eliminated the time consuming hand procedures; however, Operations Research techniques have not been greatly utilized, partially because of the combinatorial problems associated with *realistic* large scale models. This paper examines the current large scale methods, and a synthesis of simulation, linear programming, and integer programming is proposed The technique is illustrated in a faculty assignment problem with preferences.

SS1A.34. Prototypical Forms of Dialogue for Metropolitan Planning, CHRIS McDONALD and DAVID E. BOYCE.
Metropolitan planning requires a particular process which:

a) integrates the capabilities of specialist professionals and agencies;
b) is responsive to public inputs and political controls;
c) is meaningful, flexible and efficient.

A formal diagrammatic language is specified which portrays the planning process in terms of:

a) the pursuit of procedures within specialist activity streams;
b) the passage of consequential messages between those streams.

Despite strong assumptions about the sequentiality of careful dialogue, the branching and interfacing of individual chains is represented vividly. A variety of basic procedural options results. These are assembled into richer and more realistic prototypes, having distinct planning capabilities and resource implications.

SS1A.35. Use of an Incident Seriousness Index in Development of Police Patrol Manpower, J. THOMAS McEWEN and NELSON HELLER.
A measure of the demand for police service has been developed which incorporates the seriousness of the incidents. The measure reflects the extent of physical injuries, property losses, and anxiety of the incidents. Volume and service time requirements have also been incorporated. The demand measure provides supplementary statistics to the UCR counts of offenses and also serves as a new input to the scheduling and distribution of both preventive and call-for-service patrols.

SS1A.36. Housing and Racial Transition; The Process Policy Implications, DONALD PHARES and ELDON MILLER.
The focus of the paper is racial transition and housing in an inner suburb of St. Louis, Missouri. The first section delineates the nature of transition and its impact on urban development. The empirical component of the paper examines the relationship between transition and the value of property. Neighborhoods are defined to permit comparisons across areas experiencing varying degrees of racial change and empirical examination of the impact of racial change on the value of residential property. The final section discusses the institutional arrangements that are available to communities in dealing with transition.

SS1A.37. Public and Community Relations as an Answer to the Social Problems of Urban Fire Departments, ALBERT PINES.

This paper discusses the symptoms surrounding the problems of harassment and abuse under which our urban fire departments are presently suffering. Discussing these problems in relation to the changing urban environment, a combined program of public and community relations is suggested as a possible solution to at least part of the problem. A course of action to increase the social responsibility and awareness of the fire fighters themselves is also discussed as a necessary part of the solution to the whole problem.

SS1A.38. A Branch-Select Algorithm for the Capital-Budgeting Problem with Interrelated Projects, R. RAMALINGAM.

An Algorithm for determining the optimum solution for the selection of projects with constrained resources is presented. Selection of projects is made by using the concept of Ratio-Analysis. The criterion is to maximize the total profit or sales revenue. A decision tree incorporating upper bound and lower bound for its nodes is used in arriving at the optimum solution. Numerical examples are presented to illustrate the computational procedure. Applicability of this Algorithm in areas such as cutting stock, production scheduling and network reliability and also its extensions for elastic and mixed restrictions are discussed.

SS1A.39. The Motor Vehicle Operating Cost Function, SAMUEL W. ROSS.

The multivariant price structure of tangible vehicle operating cost can be expressed as a function of vehicle performance to the transportation network. Unit operating costs have been related to running velocity and operational delay for various roadway and traffic conditions. Adding a value for the user's time and a cost for accidents on the route, it is possible to utilize parametric programming to construct the total vehicle operating cost vector. This price solution as a criterion in the urban simulation network is presented for application in modal split, trip assignment, optimal signal timing, and cost-effectiveness of capital improvements.

SS1A.40. Restructing the Inner City Marketplace by Simulation, DONALD E. SEXTON, Jr.

Urban blight has severely weakened the inner city market. The choices open to the inner city consumer generally consist of relatively lower quality products at relatively higher prices. The structure of the marketplace—numerous small retail outlets—is one reason underlying this situation.

This exploratory study seeks to evaluate various alternative retail market structures (e.g , large cooperatives). Each structure is evaluated not only according to expected price levels of products sold but also according to expected amounts of services (e.g., convenience) offered. The hypothetical marketplaces are examined by a simulation (GPSS) based on data from a Harlem survey concerning shopping habits and store selection criteria of consumers.

SS1A.41. Class and Subject Scheduling in A Further Education College, P. R. SHELTON.

The problem considered is that of planning a schedule for a college providing tuition for courses which involve a student in studying two or three specialist subjects for two years. The planning requires that as many subjects and combinations of subjects as possible are offered, within restrictions imposed by the number of staff, room availability, hours of teaching per week, etc., while keeping the actual timetabling of classes as simple as possible. Amendments which ease one set of restrictions, but thereby impose others, are considered.

SS1A.42. A Needs-Oriented Systems Perspective of the City, J. TALAVAGE and W. CRICHTON.

The need is demonstrated for a systems approach to the study of urban

problems. A comprehensive model of the city, from a planner's viewpoint, is given showing various subsystems in interaction (health, transportation, law enforcement, etc.) and showing the contribution of each subsystem to the needs of the community members. Discussion is given of the use of the model as an educational tool and as an aid to information flow among governmental and industrial planners.

SS1A.43. A Method of Establishing Traffic Signal Warrants for Heavy Traffic Volume Occurring During A Short Time Period, JASON C. YU and VINOD CHACHRA.

Current traffic signal warrants are recommended on the basis of continuously uniform traffic flow rather than the short burst traffic flow consideration. This study was to consider a unique method of establishing a realistic traffic signal warrant for specific intersections where heavy traffic volume occurs only during short time periods In approaching this objective, economic analyses, statistical methods, simulation studies, empirical procedures, and theoretical methodologies were blended and directed toward practical solutions of the problem. The economical analysis was of material assistance in the solution of the benefit-cost ratio of such a traffic signal warrant. A microscopic simulation model was formulated, programmed, tested, and refined. This model described traffic performance and control at individual intersections while permitting a full range of traffic characteristics, either for control purposes, or to gauge effectiveness of operation. Certain field data were collected to build realism into the theoretical considerations.

SS1A.44. A Functional Description of The Police Patrol Vehicle, JAMES E. BAILEY and HERBERT G. LUDWIG.

The purpose of this paper is to present a systems definition of a more functional urban patrol vehicle. The vehicle system is related to a "critical incident" model of the patrol function. The description is presented in terms of:

1. Departmental policy limitations
2. Critical role definitions
3. Equipment utilization statistics
4. Human factor requirements

This paper is a report on a portion of the conclusions of a Department of Justice sponsored research effort entitled "The Police Patrol Vehicle."

SS1A.45. A Systems Analysis of Police Vehicle Ownership, HERBERT G. LUDWIG and FRANCIS E. PLONKA.

This paper discusses a management oriented systems analysis of the procurement–maintenance–replacement cycle of a police vehicle. The analysis includes an examination of each step in the cycle and a determination of the policies, information flow and decisions required to support this cycle. Problems have been defined, and solutions offered to these problems are discussed. The paper discusses ths role of management information systems in the maintenance and operations of police fleets of various sizes. This paper is a report on conclusions of a Justice Department research project entitled the "Study of the Police Patrol Vehicle."

SS1B.1. Simulation of City Politics, FRANK L. ADELMAN and IRMA ADELMAN.

As part of a projected simulation of the social, political, and economic character of an urban community, a simulation model of the political subsystem of a large city has been constructed. The model assigns utility functions and decision rules to the aldermen and mayor of the city, who take into account both potential votes and job and favor patronage. A bargaining submodel is included, and the roles of the mayor, the media, and community interest groups are taken into account explicitly. The operation of the model and the validation process will be discussed.

SS1B.2 A Proposed Methodology for Correlating Cultural Environments and Potential Management Innovation, LESLIE P. ANDERSON, and FREDERICK C. WESTON.

This paper places major emphasis on relatively undeveloped countries and is addressed to the basic question: "Given certain data about a country's culture, or a sub-part thereof, is it possible to measure and predict management's innovative capabilities?" The research is addressed to determining, in broad categories, to what extent management innovation is a function of cultural variables weighted to make a composite evaluation of educational, sociological, legal, political and economic factors. The authors postulate that it is feasible through a multivariate discriminant analysis of the social and institutional variables, weighted through an application of the Delphi process, to divide cultural environments into classes of *high, average* or *low* in terms of their conduciveness to management innovation.

SS1B.3. Geographic Market Potential and Performance: An Evaluation Technique, M. N. BARTAKKE and W. A. HALL.

Determination and evaluation of geographic (county) market potential and performance is a major problem of marketing management. Having the ability to determine geographic business potential, management can allocate territorial resources in an optimum manner. This involves making decisions depending upon the answers to the following types of questions:

- What is the performance or potential of a particular county or group of counties?
- Where should branch or resident offices be located?
- Should the marketing efforts of two or more branches be consolidated? If so, what counties should be included in the consolidation?

This paper describes an econometric model that was developed to determine total computer or Univac's potential business at county level. The model has the ability to pyramid the results from county level to branch, region, or zone offices of Univac.

SS1B.4. Measurement of Individuals' Priorities for National Goals, JAMES R. BETTMAN.

A major task for social measurement is that of assessing national priorities. Accordingly, this study develops a methodology for measuring individuals' priorities for national goals on an interval scale, and suggests multivariate procedures for interpreting such scale values. The scaling procedure used is a paired comparison paradigm developed by Bechtel. This scaling procedure is outlined and a test-retest procedure is discussed. Multivariate analysis of variance, discriminant analysis, and cluster analytic procedures are then outlined for gaining policy insights from the scale value data. Finally, this methodology is applied to an empirical example concerning national priorities for eight possible national goals.

SS1B.5. Evaluation of Innovative Programs in Urban Education, FRANCIS M. BETTS,III.

Innovative programs in urban public education have gained prominence in the 1960's as a response to an expressed community need for improved educational opportunity. If such programs are to achieve viability, they must be conceived and tested within the existing educational system rather than independently.

Traditional methods for program evaluation seem inadequate. Using as a case study an innovative community school within the public educational system in Philadelphia, selected operations research techniques are used to explore an evaluative routine for innovative urban educational programs. In addition to the management sciences, the disciplines of anthropology, sociology, psychology, architecture and urban design, and education are involved.

SS1B.6. Ethics and Operations Research, DONALD B. BROUTT.

Operations Researchers have central responsibility to promote man's living as man—to promote exercise of individual rationality for productive work in freedom from physical force. We will destroy our progress towards higher productivity unless we stop our unethical efforts to create stronger, more effective, government. Rather, we must demonstrate that the quality and quantity of life and production can only be optimized through free markets, unrestrained in all respects except prohibition against initiation of force. Approaches to social and environmental problems suggested at this meeting illustrate the danger to our freedom.

SS1B.7. Managerial Effectiveness in Systems Operations, ROBERT A. BROWN.

As man-organized systems become larger and more complex, a crisis in the measurement of managerial effectiveness develops. Present methods of organization and control are inadequate for two reasons. First, the dynamics of the system are largely ignored in assessing managerial effectiveness. Second, even though attempts at quantitative treatment are made, there is no unifying theory of management-system interaction; the criterion problem of assessing the significance of system deviations is unsolved.

This paper describes a man-organized system model and a method of implementation. The system model specifically treats system kinetics so that a measure of managerial effectiveness can be defined. Finally, studies are described showing favorable results in applying the method to both computer simulations and real man-organized systems.

SS1B.8. Programming Approach to the Criminal Justice System, R. G. CASSIDY.

The main purpose of this paper is to develop an analytic model for the criminal justice system with the use of mathematical optimization models. The basic models are composed of unconstrained and constrained mathematical programming models which have the form of geometric programming problems. By using branching ratios as variables for the mathematical programs, the models define optimal branching ratios for various blocks (such as arrest or trial) within the criminal justice system. The difference between these optimal branching ratios and the existing ones locates certain blocks within the criminal justice system where more research is necessary in order to increase the effectiveness and reduce the cost of the total system. An added advantage of using the mathematical programming approach is that a methodology is developed to comparatively evaluate rehabilitation programs which exist within the incarceration block of the system and observe the effect of the various programs upon the system as a whole. Thus the mathematical programming approach to the criminal justice system provides a new and effective method for analysis of the system and the development of changes within it.

SS1B.9. Cybernetics and Educational Evaluation, YING C. CHUANG.

With the advent of computers, the feedback control theory of cybernetics has been widely applied in various areas of engineering. The application of cybernetics theory has not yet brought about a system approach to educational problems in general and to educational evaluation in particular. This paper will present and illustrate the application of cybernetics theory to educational evaluation and some of the implications for implementing it.

SS1B.10. An Effectiveness Evaluation Model for Community-Based Social Services Delivery Systems, ROBERT M. CLINKSCALE and MARILYN P. RYMER.

One of the most challenging systems problems of the 70's is welfare reform and the establishment of effective social services delivery systems. The state-of-the-art with respect to cost-effectiveness measurements related to social services is in its infancy. The purpose of this paper is to describe a computer-based social services effectiveness evaluation model designed to measure the extent to which social services goals and objectives are realized. The model is policy-oriented and designed to provide data related

to client socio-economic characteristics and social service needs, case objectives, prescribed social services, and client progress over time, use of agency and community resources, and a determination as to whether the recipient is made more or less dependent upon the "system" in the future The model is currently being used to evaluate a community-based social services center experiment funded by HEW as a national demonstration project. Conceptualization and development was carried out by an interdisciplinary team representing economics, operations research, and social work.

SS1B.11. A Systems Approach to Societal Problems. DAVID A. CURRY.

This paper reports on a systems study of societal problems for which the objective was to identify neglected or underfinanced problems of highest priority and their plausible causes. Problems were divided for this purpose into three levels: substantive types (poverty, pollution, racial and international conflict, etc.); process types (reasons why solutions cannot be reached or agreed upon, such as lack of long range planning or coordinative groups, or unintegrated specialization); and value types (decline in a common sense of personal values, overemphasis on efficiency criteria or economic growth, etc). Solutions were characterized as systemic, preventive, ameliorative, and compensatory. Major conclusions included·

- There is substantially no hope of "solving" substantive societal problems through the usual ameliorative and compensatory means, or at foreseeable levels of effort.
- Much more attention to process and value types of problems or questions must accompany any serious effort at societal problem solving.
- Our true national goals, which can be roughly surmised from resource allocation decisions and indicators of social performance, have little relation either to our professed goals or to serious societal problem solving.

SS1B.12. Determination of the Defensive Versus Offensive Payloads of Strategic Bomber Aircraft to Obtain Maximum Target Destruction, MAJOR JOHN R. CURRY, JR., USAF.

Under certain assumptions the survivability of a strategic bomber is a function of the number of defensive weapons it carries and its kill potential is a function of the number of offensive weapons available and of their point of launch. A Monte Carlo air battle simulation is used to obtain an expected value of survivability for each possible defensive weapon load configuration, and a dynamic programming technique is used to allocate offensive weapons to targets under the predetermined survivability conditions, giving a load configuration for the maximum target destruction.

SS1B.13. The Application of Operations Research to Social Welfare Planning at the Jewish Community Federation of Cleveland, BURTON V. DEAN, ROBERT REICH, ARNOLD REISMAN, ALLAN L. SERVICE, ARTHUR BLUM, RAYMOND KOLESKI, MIRIAM JAFFE, HOWARD RIEGER, RICHARD RONIS, and JUDAH RUBINSTEIN.

A major application of Operations Research in the context of a voluntary federation of social welfare service agencies is described in detail. The organizational structure and decision-making processes of the Jewish Community Federation of Cleveland are outlined, as is the initial development and structure of the multi-disciplinary research team. The application itself is then delineated with attention paid not only to the final product of the research and its implementation but also the evolution of that product's components during the course of the three-year project. The core of the work is a technique for assessing the "output" of the system of agencies in a consistent and operationally useful manner. Use of the measurement model as a planning and budgeting tool is also indicated.

SS1B.14. Systems Analysis, Operations Research, and Social Systems, S. J. DEITCHMAN.

Social systems are defined as systems in which the key interacting elements, and the links between them, are human rather than technical or technological. The operative distinction between technological systems, for the design and analysis of which SA/OR were developed, and social systems, to which SA/OR practitioners are increasingly turning their attention, is postulated as follows: in technological systems the elements and links are rather predictable and in large measure can be made responsive to the will of those who design, build, and operate the systems; whereas in social systems the elements and links have minds and wills of their own and therefore are likely to be unpredictable, unresponsive, and far harder to deal with by SA/OR techniques.

The paper will enlarge on this distinction. Starting with descriptions of the key elements and links in typical examples of the two kinds of systems, the processes of design, construction, and evaluation will be examined. The influences of various objectives and motivations among system planners, evaluators, and operators as they affect the creation and performance of the two kinds of systems will be highlighted. Since the design and evaluation of system performance depend critically on measurement of input, output, and error, the measurement and prediction problems will be compared for technological and social systems. Social systems demand understanding and research in the social sciences, whereas technological systems can be treated by more familiar operations research and systems analysis techniques. The two will be compared, with emphasis on the problems of data gathering and analysis in the field, and possible avenues of reconciliation between the two disciplinary areas.

SS1B.15. The Social Security (HEW) Evaluation and Measurement System, JACOB DEUTCH, SYLVAN HACK, and SAUL D. HEARN.

This paper describes a computerized statistical sampling and analysis system which furnishes continual information as to the effectiveness of the Social Security Administration's claims policies and procedures on a timely, scientific, and objective basis. Each month, a stratified probability sample is selected from newly adjudicated claims. An intensive redevelopment of these claims is conducted. On a random independent basis, differences and agreements between the original and subsequent claim developments, within selected areas of interest, are coded and introduced into a comprehensive computerized system which conducts the desired comparisons and analyses. The techniques for preserving the validity of the system itself are also described.

SS1B.16. Sociotechnological Forecasting, J.N. FOX.

Anticipation of the future, even by recognized professionals, has frequently met with skepticism. In the advancement of science, we find an enormous spectrum of future events with broadly varying probabilities of occurrence. Science often deals with probabilities, and the difference in the performance of a complex technological system and in predicting a much broader future sociotechnical event is merely an expansion into areas where results consist of less reliable and less precise descriptions. If we are to apply logical and objective thought in assigning probabilities of occurrence of anticipated events and the time periods in which they most likely will occur, more analytical and creative thought must be devoted to technological forecasting

SS1B.17. Day Care Centers—An Analysis Overview, DENNIS M. GALVIN.

Day Care programs for preschool children will be one of the new emerging educational and social institutions of the 70's. This emergence is attributed to the multiplicity of social and economic benefits of Day Care programs coupled with the changing role of the working mother in our society.

This paper presents some of the basic issues of Day Care (primarily economic) and how the Operations Analyst can enhance effective decisions in the development and maintenance of quality Day Care Centers. The importance of decision making that optimizes economic, social, and educational benefits is highlighted.

SS1B.18. An Application of the Systems Approach to Educational Planning, P. C. GEORGALLIS and P. H. NISBET.

The systems approach, acclaimed as a significant breakthrough in military and space systems planning and management methodology, has met with only limited success in the socio-economic field. Recently, a rare opportunity was presented to employ this approach in the development of plans for a major educational program. Its application forced political and other priorities to surface which conflicted with the nominal goals of the program. The proposed paper will define the means used to apply the approach to educational planning, discuss the problems faced, assess the results, and recommend viable means of applying systems methodology to future socio-economic programs.

SS1B.19. Sharing Responsibility for the Ethical Use of Technology, RICHARD D. GOODFRIEND.

In applying the results of technological advances for supposed public benefit the technological practitioner should bear certain responsibilities for the ethical use of technology. However, there are often limitations imposed on practitioners by the organization that employs them, directly or indirectly, whether it be private or governmental. Therefore there exist certain other responsibilities that must be borne by the immediate and/or ultimate employer. This paper examines some of the ethical responsibilities of the individual versus those of the organization and discusses the premise that a balanced sharing of responsibility should generate attitudes and interactions that would benefit the public.

SS1B.20. New Horizons in Application of Systems Sciences to Management, RICHARD M. GREEN, JR.

A thorough examination of some of the new discoveries in systems sciences reviews some of the basic hypotheses of how systems operate. These then are applied to management. Among the discoveries are these challenging principles: There is no way to place responsibility upon a manager for past performance, only future assignments can be held responsible to managers. Secondly, in predicting the future, the less data about the past which is used, the more valid the prediction under certain circumstances. These and many more are discussed and practical examples from company applications are provided.

SS1B.21. Evaluation of Transportation Plans: A Survey of Methodologies, GEORGE D. HALUSHYNSKY.

The paper presents a survey of evaluation methodologies for transportation plans in a tutorial framework. The importance of developing proper objectives and a sufficient range of alternatives is strongly emphasized. Two general classes of models are discussed. The first class consists of benefit-cost, linear and dynamic programming models, which emphasize quantifiable economic objectives. The second class is represented by goals-achievement, rank-based expected value, effectiveness matrix, utility matrix, and scoring models, which measure the benefits and costs of all applicable objectives in units which are relevant to the particular objectives. Suggestions for successful model usage complete the paper.

SS1B.22. A Means of Quantitatively Assessing the Effect of Lawyer Behavior on Court Management Performance, ROBERT HOWARD.

Systematic analysis employed in court administration have concentrated upon analyzing the functioning of the court. Generally they have overlooked the importance of the multiplier effect which results from the fact that approximately 90 percent of the cases never reach trial. Thus, small changes in the fraction of cases settled produce large changes in the judicial workload. The settlement of cases is highly dependent upon the behavior of the defense and plaintiff attorneys. This paper confronts the problem of developing a method of quantifying lawyer specialization. It also considers utilization of such information within the context of the court congestion problem in civil proceedings in federal district courts.

SS1B.23. Micro Analysis in Higher Education Decision Making, ROBERT C. JUDD.

The micro analytic technique applied to decision making in higher education has been described by Barton, among others. Applications of this technique to curriculum planning and course sequencing are reported in this paper as encountered in the student records from a state university. The advantages of micro analysis over macro analysis are discussed.

SS1B.24. Modeling a Responsive Message Exploitation System, LT. JOHN C. MAYSON, III, and PATRICK B. SAMPEY.

The Current Intelligence Traffic Exploitation System (CITES) Model was developed at Hq U.S. Strike Command using 360/GPSS. The model simulates the flow of messages through a computer system requiring: message receipt; message header analysis and editing; automated distribution through visual display interaction; and review, storage, and retrieval through remote terminals.

The model is being used to validate system design and aid in modifications to the system. Console display stations can be closed for varying times to study the effect on the queues. Abnormally high message volumes can be generated to evaluate the proposed equipment, personnel and system interaction to function under stress conditions.

SS1B.25. Dormant System Maintenance Value Analysis, CHARLES C. KELBER.

Systems of the Seventies will include a strategic defense system, one of whose most costly components (the deployed interceptor sub-system) is a dormant one whose function is an expendable, one-shot utilization of the hardware. Under a realistic economic constraint, such as annual budget and/or total life-cycle system cost, the system analyst or planner is faced with the problem of optimum resource allocation among RDT&E, Acquisition, and Operations. It is the purpose of this paper to present a Cost-Effectiveness criterion for selection of a Maintenance Policy for stand-by systems, as it is affected by the interdisciplinary considerations of reliability, maintainability, human factors, and cost-effectiveness. It seeks to determine if the electronic industry has not already achieved that state-of-art of reliability and long life which eliminates the economic attractiveness for conventional check-out and corrective maintenance of dormant systems.

SS1B.26. Programmed Goals–Achievement Matrices for Selecting Alternative Public Investment Plans, THEODORE KLASTORIN and TIMOTHY RUEFLI.

Goals-achievement matrices have been employed to evaluate alternative plans for public investment in urban and regional development. Such matrices, however, have been limited to the evaluation phase of the decision process, largely due to the difficulty of managing complex systems of multiple objectives. This paper presents a process, based on goal programming, for extending the use of goals-achievement matrices into the process of alternative public investment selection. Currently available computer packages and programming techniques are employed and an example is presented.

SS1B.27. Cost–Effectiveness Evaluation of the Volunteer Army Field Experiment, WILLIAM A. LINDSAY.

With considerable attendant publicity, the US Army has embarked upon an ambitious program to induce greater numbers of young men to choose a military career so that reliance upon the draft may be eliminated. This Modern Volunteer Army (MVA) program was inaugurated during 1971 with a series of field experiments at designated posts, designed to determine what changes in Army life are most conducive to improving personnel retention, performance and morale. This paper reports the methodology and preliminary results of a cost-effectiveness evaluation of the experimental program. Results of the study will provide criteria for determining which projects have the highest pay-off in terms of reenlistment potential.

SS1B.28. Analytic Models of Criminal Court Operations, NORMAN R. LYONS.

Two models for dealing with the problems of large criminal courts are

presented in this paper. The first is used for projecting the long run workload of a criminal court. It is a stochastic model that enables an administrator to estimate the number of cases processed, the backlog at the end of each period, and the expected overschedule and underschedule associated with the forecast. The second model draws on inventory theory for the scheduling of short run caseloads. In this model, it is assumed that the number of judges in the system is fixed for the scheduling period, and the question facing the administrator is one of choosing the number of cases at each calling period so that waiting costs and underscheduling costs balance each other. The models are tested and validated on a simulation program whose parameters are drawn from the criminal court in a major American city.

SS1B.29. Ex Ante Hardness of Data Analysis: An Approach to the "Soft Data" Creditability Problem, D. V. MATHUSZ.

Some of our most pressing problems in urban development, political economics and psywar are dependent upon "Soft Data" for their analysis. The controlled reproducibility of such data is low to nil, with its elements of subjectiveness and inherent definition difficulty in terms of the rigor of classical dimensional analysis.

The approach advocated here is to identify ex ante, the relative reproducibility of soft data in terms of its source type as identified by the collection mechanism imposed of necessity by its predesigned query responses. These are worked into an ordinal hardness of data scale used in both the data design phase and subsequent analysis. Regions of relative hardness can thus be identified (say) in regression analysis curves. The work is currently exploratory but some preliminary applications are given.

SS1B.30. A Mathematical Programming Model of Educational Planning with Quantitative and Qualitative Sub-Objectives: A Case Study of Korea, LEO Y. MIN.

In this paper a centralized educational planning model is developed which combines numerical and logical analyses. The model is then applied to South Korea using data collected during 1968 to 1969. A concept of mapping process is introduced to map the real objectives and constraints into the perceived objectives and constraints. Based on these perceived objectives and constraints, a linear programming model with multiple sub-objective functions is constructed. The rates of return to educational investment are calculated by computer simulation. Weighting functions are introduced when the decomposed educational objectives are synthesized. The optimal solutions for each sub-objective function are obtained using IBM 360/67.

SS1B.31. The Relationship Between Formal Procedures for Pursuing OR/MS Activities and OR/MS Group Success, RODNEY D. NEAL and MICHAEL RADNOR.

The paper compares the formalized procedures for pursuing OR/MS activities advocated in the literature with what is currently being utilized in the field. The data is based on personal interviews with some 160 OR/MS managers, practitioners, and clients in 108 large business firms. Each OR/MS group is rated on the basis of policy and procedural elaboration practiced and its success scored on several dimensions. The relationship between proceduralization and success is then tested and found to be significant under a variety or organizational circumstances, but varying with the circumstances. The implications these findings have for the management of OR/MS groups is discussed.

SS1B.32. Effective Utilization of OR/MS Consultants, FREDERIC K. ROSEN.

This paper will provide guidelines to allow Corporate R & D Managers to successfully utilize consultants engaged in providing OR/MS services. In particular, considerations that will be investigated include.

1. When is it necessary and economical to utilize consultants?
2. Key considerations in contractual obligations.
3. Monitoring and control of progress and expenditures.
4. Evaluation of results.

5. Normal and exceptional termination of efforts.
6. Implementation and utilization or results.
7. Pitfalls and detrimental situations to avoid.

SS1B.33. On the Business of Science, FRANCISCO SAGASTI and PRAFULLA JOGLEKAR.

Science is the business of knowledge. This paper attempts to contribute to the self examination of Science. It uses the multi-national mega-firm as a "model" for the representation and understanding of the Institution of Science. By transferring some concepts of business planning and management through the use of this analogy, it is possible to obtain new insights into the area of Science policy, both at the national and the international level. The diversity and the decentralized character of the scientific enterprise are also considered. The role of operations researchers in planning, development and orientation of science and technology is analyzed in some detail.

SS1B.34. Personal Accountability and Ethical Use of Technology, ROLAND SCHINZINGER.

When there is a conflict between professional judgement and organizational practices the employed professional may find it hard to assure ethical use of technology. Yet he is apt to be held accountable under the law, correctly so. While most will agree in matters pertaining to proper conduct, there may exist differences of opinion in the assessment of a new technology's impact on the natural and social ecology. This may require discussions in the public arena. The paper will examine the predicaments of the professional as an employee and as a public figure.

SS1B.35. Professional Decision Making, JEROME H.N. SELMAN.

What tools are available for the professional decision-maker? Can logic and rationality or psychic perception and precognition take the decision-maker better along the royal road from correct decisions to successful outcomes? The complexity of problem-finding and problem-solution of major systems orients the decision-maker to heuristic and eclectic approaches which question the "eternal verity" of rationality. Various paradoxes will be reviewed to show the pitfalls of consistency vis-a-vis real world problems, and to give ego-strength to the decision-maker in light of encoding and using his subjective judgment.

SS1B.36. How Much is Your Life Worth?, JEROME H.N. SELMAN.

The price tag you put on life depends upon whether you think life is priceless or worthless. Increasingly in cost-benefit, effectiveness analysis of Man-Machine systems, the "value of life" must be inputted to the total cost model. Although complex, the problem is neither intractable nor capricious as Society imputes values, as evidenced by mandatory vehicular safety devices and vulnerability requirements for military aircraft. Values range from almost zero to $3,000,000, with actual court awards up to $2,000,000! The audience will put values on their lives using the decision-analytic structure of the ingenious Russian Roulette examples of Zeckhauser. (cited by Raiffa).

SS1B.37. New Implementation Models of "O.R.", A. FOUAD SHERIF and FAREED R. ELNAGGER.

Mechanistic implementation models of "O.R." could be criticized for different reasons: (a) Non-developmental (b) No interaction between O.R. practitioners and the client organization (c) lack of growth and organistic nature. Our case studies show high rate of rejection of such mechanistic use of O.R. models. New "Organistic Implementation" models are proposed to enhance the marketability of the O.R. techniques and to assure their practical effectiveness. These new orientations improve the problem solving capability in the process of consulting instead of submitting cut and dry resolutions.

SS1B.38. Commodity Allocation: A Voting Model Approach, WILLIAM R. SHERRARD and ROBERT L. BUTLER.

This paper develops a voting model, which, given an initial allocation and certain voting rules, determines whether a decision-making body's motions for wealth reallocation will succeed or fail. It is assumed that the commodity being allocated has positive value to all voters and is infinitely divisible. The most likely candidate for such a commodity is money. The model considers the reallocation process with and without side payments allowed. The latter is akin to situations which permit lobbying. Early in the paper it is shown that motions which alter the ranking of individuals in a group, as determined by wealth, are inconsistent with the assumption of voter rationality. Thus, given the constraint that wealth rankings within the group cannot be altered, the paper evaluates several situations relative to reallocation proposals which may come before the group. The latter include proposals for (1) the equal distribution of the group's wealth, (2) the reallocation of the wealthiest voter's holdings among the other voters in the group, (3) the reallocation of wealth where members of the group have one vote for each unit of the commodity held, and (4) the case where members are allowed to make side payments to other members of the group.

SS1B.39. Application of a Flexible System to Retrieve, Manipulate and Display Information from a Stable Questionnaire-Oriented Data Base to Social Science Research, CHRISTOPHER R. SPRAGUE and DAVID NESS.

A significant trend in media planning has been the appearance of large syndicated data bases generated by questionnaires covering demographic, media audience, product consumption, and psychographic data, together with highly efficient, interactive systems for retrieving data so as to explore relationships among variables. These systems, and to some extent, the underlying data, are potentially of value in Social Science research. This paper details one such example, a study of the relationship between income from primary occupation and income from other sources.

SS1B.40. The Dilemma Between Planning and Freedom of Action, JOHN P. VAN GIGCH, ABBASS BARZGAR, and R. DURGIN.

In the name of optimization, systems analysis demands that more order and organization be imposed upon systems, decision-makers and agents. It would appear that the price that must be paid to systematize is a loss in freedom. The value system behind the concept of freedom is studied to explore the justification for applying more constraints in the name of systems optimization. The trade-offs between planning constraints and freedom of action are considered in order to resolve the dilemma of social action which seems to require more planning, intervention, and controls, and hence more infringements upon the individual's freedom of action.

SS1B.41. The Assumptions of Systems Analysis, ERNEST H. WEINWURM.

Systems analysts consider their work to be objective in accordance with the requirements of the scientific method which involves a complete statement of all assumptions. However, this is not true though they may not be aware of the discrepancy. Like others doing research involving humans, systems analysts assume a specific social-economic framework-background within which they operate.

The paper will concentrate on an analysis of the presently used assumptions but will also discuss some of the changes which may be required in the future to meet different developments. This problem should be of major concern to the profession of systems analysis.

SSIB.42. Transportation and New Communities, MARCUS S. WEISS.

How will new town concepts and related transportation systems deal with the problem of racial separatism? It appears that we are continuing the system of ignoring

racial separatism as we attempt to propose new systems of transportation in existing metropolitan areas as well as in new towns and communities. The role of racial separatism in the present and especially in the future will be crucial to the success of our attempt to revitalize the cities of America. In this paper I will deal with the relationship of transportation and racial separatism to the design of major metropolitan areas.

SS2A.1. An Analysis of Key-Stroke Errors Undetected by the Zero-Sum Check, STEPHEN G. ALLEN.

The record of a transaction in a customer's bank account consists of an account identification and three numbers z, x, and y which have the property that $z = x + y$. For example, z may be the old balance; x a debit to the account; and y, the new balance When an operator has keystroked a transaction, a test is automatically made that the triple (z,x,y) actually keystroked satisfies the zero sum check, namely, that $z - x - y = 0$. If not, a signal to check for an error is given. However, it is possible that an error made in one number in the triple may be compensated by errors made in either or both of the remaining numbers. In this case, the zero sum check is satisfied but the key-stroke errors will not be detected (at least automatically). It is the purpose of this paper to analyze situations in which undetected errors can occur, to compute the probabilities of undetected errors, and to estimate these probabilities.

This information was essential in designing a transmission system for recording transactions at a central data processing center for a large branch banking complex. However, it would be important in the design of any computerized inventory control system.

SS2A.2. A Bus-Traveler Algorithm for Single Destinations, DEAN N. ARDEN, HELMAN I. STERN and THOMAS A. WILLIAMS.

In this paper the authors describe a scheduling and routing algorithm for the assignment of buses to travelers, all of whom wish to be transported to the same destination. The scheduling algorithm is designed to minimize the maximum waiting plus travel time of any traveler by making the assignments based upon a wide variety of cost functions which may depend arbitrarily on the available data. The algorithm has the ability to change previous assignments based upon new demands or changes in the structure of the transportation network, and can be readily implemented in a real time environment.

SS2A.3. Autoregressive Moving Average Models for Forecasting Telephone Movement, SUDHIR K. ARORA and AMRIT L. GOEL.

In this paper we develop forecasting models for the inward and outward movement of telephone connections for the Syracuse metropolitan area. The methodology adopted for building these autoregressive moving average (ARMA) models consists of three stages; identification, estimation and forecasting, as proposed by Box and Jenkins. It is seen that the problem of fitting a suitable ARMA model in this case is simplified by performing simple transformations on the original data. Also, APL programs are developed and their usefulness in constructing such models using an interactive approach is demonstrated.

SS2A.4. Linear Programming as a Budgeting Tool, JOSEPH H. AUGUSTA and NORMA J. HIBBS.

Linear Programming is an optimization process; the planning phase of budgeting aims to optimize resource allocation. Thus, budgeting represents a natural application of linear programming. This paper presents a scheme incorporating linear programming and Leontief interindustry economics. It applies it to military budgeting problems, where in an environment of changing force requirements and declining budgets, the goal is to distribute support resources to maximize support to forces. The non-trivial problems of finding approximate mixes of inputs and outputs implied by different budget levels are considered. A systematic procedure for evaluating alternative support profiles is presented.

SS2A.5. Parellel Processing and Integer Programming, EGON BALAS.

The solution of an integer program in n variables can be reduced to the repeated solution of n auxiliary problems P_i,i = 1,...,n, such that (a) each auxiliary problem can be solved independently; (b) a certain (unknown) subset S of the set of auxiliary problems has the property that the solution of each $P_i \in S$ generates information accelerating the solution of all P_k, $k = 1, \ldots, n$, $k \neq i$. As a consequence, solving the n auxiliary problems in parallel rather than sequentially can save not only time, but also computational effort as measured by the total number of arithmetic operations to be performed. This throws new light on the significance of creating parallel computing facilities in the form of parallel processors and/or computer networks.

SS2A.6. Optimization of a Multi-National Physical Distribution System, M. N. BARTAKKE, J. V. BLOOMQUIST, J. K. KORAH and J. P. POPINO.

Optimization of a multi-national physical distribution system with factories, warehouses, and demand centers is of great importance in international business activities. The paper discusses the various parameters of such a system. The optimal locations and sizes of the warehouses are evaluated by solving a mixed integer programming problem. Criteria in computing the freight-in cost, freight-out cost and the inventory level are listed. Computational experience using Balas' implicit enumeration technique is also discussed. An incremental analysis to help the operating Management in implementing the result is presented. Further study possible in this direction, if pertinent data are available, is also discussed.

SS2A.7. Measuring Spatial Interactions. Gravity and Some Alternatives, MARTIN J. BECKMANN, THOMAS F. GOLOB and RICHARD L. GUSTAFSON.

Traffic demand as a measure of general spatial interaction is developed through aggregation from utility maximization by decision making units (households) operating under constraints of expenditure, time, and automobile ownership. Relevant predictors are identified. Gravity is derived through specification of utility as a weighted sum of logarithmic or power function, and elasticities of demand are calculated. Piecewise linear utility functions, generating resistances in step function form, are estimated by regression using dummy variables. Thus, empirically estimated resistance functions are obtained as the basis for improved spatial interaction models, and hypotheses on underlying utility functions can be tested.

SS2A.8. Conversational Computerized Statistical Analysis in Business, JOE BULAT.

A significant application of the computer is in the area of statistical analysis of data for managerial decisions. The problems with existing computerized statistical systems will be evaluated within the framework of management's requirements with regard to data handling, capabilities, ease of use, and costs. BASIS, a conversational statistical system, has been developed to eliminate much of the drudgery and costly delays. It permits interaction with the computer through a remote terminal for a wide variety of applications, and requires no knowledge of computer programming. Examples of the use of the system to solve managerial problems are provided.

SS2A 9. Consideration of Reliability in a Multi-State System, R. M. BURTON and W. W. DAMON.

Investigations of system reliability are usually restricted to two state systems, i.e. success and failure. This paper considers reliability in an n-state system which represents levels of gradual deterioration of the system through the several states. The transition probabilities depend upon the design of the components within the system. Associated with each state S_i of the system is the reliability, r_i, which represents the probability of successful operation of the system when it is in S_i. An example of a business firm's management information system serves as motivation.

SS2A.10. Relationship Between Optimal Capacity Expansion in Infinite and Finite Horizon Problems, ROBERT C. CARLSON.

Assuming that demand increases linearly with time and that demand must be met, the capacity expansion problem is formulated in a dynamic programming format. Both infinite horizon and finite horizon cases are treated. In the infinite horizon problem, the well-known result that optimal capacity increments are constant over time is obtained as a limiting case for the finite horizon problem. The necessary condition for the equal increment solution to be optimal for the finite horizon model is developed and then shown to be inconsistent. It is thus proved that the optimal policy cannot have equal capacity increments.

SS2A.11. Two Stage Programming Under Uncertainty: A Game Theoretic Approach, R. G. CASSIDY, C. A. FIELD, and M. J. L. KIRBY.

There have been many solution methods developed for the constrained generalized median problem in the literature. In this paper we present an interpretation of this problem as a set of interrelated random payoff games by discretizing the range of the variables in the problem. By using this approach a more general form of the problem is formulated. Using methods developed by the authors, the resulting mathematical program is solved and solutions are given for examples solved elsewhere and for more general examples resulting from the new formulation.

SS2A.12. Truncated Dynamic Programming and Network Capacity Planning, P. DOULLIEZ and M. R. RAO.

A technique, related closely to dynamic programming, for solving certain sequential multistage decision problems is presented. The characteristics of the problems for which this technique, called truncated dynamic programming, is expected to be efficient are discussed. The relationship of this method to "Branch and Bound" technique is also indicated. The method presented here is applied to the combinatorial problem of finding an optimal policy for increasing the capacity of a multi-terminal network with increasing demands over a planning period and arcs subject to failure. A numerical example is provided and computational experience is discussed.

SS2A.13. Optimal Markovian Replacement with Inspection Costs, HAMILTON EMMONS and JEAN-MARIE POIMBOEUF.

A discrete system subject to Markovian deterioration is considered under cost assumptions which include a positive cost for observing the system state. The minimum cost replacement policy, including the optimal inspection schedule, is sought. The problem is formulated as a semi-Markov decision process, and conditions are determined under which the control limit property of the "perfect information" replacement model is retained. For the case of equally spaced inspections, a simple algorithm is proposed.

SS2A.14 Consistent Preference Functions, SHERWOOD C. FREY, JR. and STEPHEN P. BRADLEY.

It is well known that when an individual assesses his preference (utility) function, the set of reference gambles and certainty equivalents that he specifies is often inconsistent and, if consistent, many preference functions will satisfy his assessments. Mathematical programming is employed to address a number of topics concerning the existence and characteristics of those preference functions, if any, consistent with an individual's assessments. The topics include: 1) generation of the set of consistent preference functions; 2) maximum and minimum value for the certainty equivalent of a gamble in the reference assessments; 3) the maximum and the minimum of the terminal value, or the probability of this terminal value, of a gamble in the reference assessments; 4) maximum and minimum preference for a gamble consistent with the reference assessments. Results are given for general as well as risk-averse preference functions.

SS3A.15. Alternate Routes Through the Simplex Method, HENRY D. FRIEDMAN.
Many textbooks introduce the simplex method using a two-dimensional geometric interpretation in which each tableau represents a corner of the simplex and each step an edge. The interpretation extends into higher dimensions: the corners and edges of the simplex form a graph which, though generally non-planar, can be plotted on a sheet of paper. The resulting graph provides special insight into the simplex algorithm when the nodes are positioned according to the value of the objective function. Cases in greater than three dimensions have been worked out to demonstrate alternate routes, degeneracy, and Beale's example of cycling.

SS2A.16. Techniques for Allocating Costs Among Participants in a Regional System, RICHARD J. GIGLIO and ROBERT WRIGHTINGTON.
Regionalization offers communities the possibility of reducing the costs of performing necessary activities. However, a community may wish to maintain any special advantage it may have and might compare its costs under the regional program with those of any coalition it can form with a subgroup from the region. This paper describes how the properties of convex sets and some concepts from linear programming can be used in attacking the resulting n-person non-zero sum game. Although the methodology was developed within context of planning waste-water treatment facilities, it is applicable to many other situations.

SS2A.17. Comparison of General Exponential Smoothing Models for Short-Range Forecasting, GENE K. GROFF.
Results of a simulation study of the short-range forecasting effectiveness of selected exponentially smoothed models for eighty-eight actual and synthetic data series are presented. Brown's six- and eight-term harmonic models are tested against constant and linear models and two seasonal factors models. The latter two models are the familiar Winters three-parameter model and a single parameter model developed by the author. Test results indicate that the four seasonal models yield approximately equivalent accuracy for most data series. If a sharply defined pattern exists, the seasonal factors models can improve forecasting accuracy. If no seasonal pattern exists, the errors of the models with seasonal components are only slightly greater than those of the constant and linear models.

SS2A.18. Set Covering Problem with Equality Constraints, D.K. GUHA.
A set covering problem can often be reduced in size by application of a number of reduction rules. The list of reduction rules is augmented here by additional rules which appear to be useful for the purpose of further reduction. These new rules indicate whether a variable must be equal to zero. If so, the variable can be dropped from the set of equations. Repeated application of these new rules along with others of the list may reduce the size of a problem considerably. Finally, an algorithm is given which appears to be well suited for this type of problem.

SS2A.19. Against a Universal Model Methodology, JOHN R. HALL, JR.
Theoretical work in the foundations of operations research is forever concerned with the existence of a general methodology for modelling problems. The works of Forrester, Skinner, and von Bertalanffy, among others, all put forward a universal theory or methodology for some branch of science This paper considers scientific research as a human activity and indicates why a valid universal methodology is likely to remain elusive. The implications of this situation are discussed in terms of the constructive use of apparently contradictory positions and methods. Ideas are drawn from Thomas Kuhn and Abraham Maslow to defend and illustrate these points.

SS2A.20. Decomposition Model for Regional Education Planning, EDWIN L. HULLANDER
The problem of planning a regional or state-wide educational system is no less

interesting and important than those of national economic planning. This paper extends previous work on parametric analysis of regional educational systems, and integrates these efforts into a decomposition framework. The decomposition model attempts to structure three important aspects of educational planning. First, to integrate the preference structure of local school districts with the global objectives of the state educational system and the implicit cost of achieving these goals. Secondly, to structure the model to evaluate the growth trends (or decline) in the evaluation of the educational system. And finally, to establish a framework for investigating uncertainty or risk components of the system, such as changes in educational objectives or goals. The model illustrates the variation in cost-benefit relationship for various regions or population strata.

SS2A.21. The Application of a Feedforward Control System for Profit Planning and Control, AKIRA ISHIKAWA and CHARLES SMITH.

Feedback control systems have been focused on extensively in discussion and writings Little attention has been given, however, to feedforward control concepts and applications. This paper, therefore, defines a feedforward control system, compares it with feedback control and adaptive control systems, describes the application of the feedforward control system for profit planning and control, and evaluates the potential for future applications.

SS2A.22. A Partitioning Technique for Obtaining Solutions to the Modularization Problem, PAUL A. JENSEN and AUGUST J. CAPONECCHI.

A significant problem in electronic system design is that of partitioning the functional elements of an equipment schematic into subsets which may be regarded as modules. The collection of all such subsets generated by a particular partitioning forms a potential modular design. The specific problem is to determine that partitioning of the schematic that minimizes a cost function defined on the subsets subject to specified hardware, design, packaging, and inventory constraints. This problem is termed the modularization problem. This paper presents a method for obtaining restricted solutions to the modularization problem by employing some recent developments in linear graph theory obtained by one of the co-authors. Numerical results from the solution of several typical problems are presented.

SS2A.23. A Dynamic Simulation Approach Solves Problems in Facilities Planning and Adds a New Dimension to Conventional Cost Analysis, L.G. KLINGEN and W.B. EVANS.

This paper describes a series of models which permits analysis of nearly all activities which take place at an airport, from the moment an aircraft enters the airport control area to the moment of engine shutdown at the gate. Runway occupany, taxi-turnoff congestion, and queuing around the terminal can be accurately evaluated. Similarly, passenger flow, ticket counter, and baggage flow models provide necessary information about activities inside the terminal. A curbside model simulates arrivals of cars and buses to determine required curb space.

Finally, the use of new methods of simulation as an integrated tool of analysis is discussed. Methods to calculate the annual penalty to the airline and travelling public of aircraft queuing delays due to congestion will be presented as well as how such information can be used to choose between alternative expansion plans.

SS2A.24. Simulating a Casualty Insurance Operation, DUANE C. KNAUER.

Casualty insurance management has been confronted with increasing pressures. A simulation model of the casualty insurance operation has provided an additional decision tool with which to evaluate proposed management action.

The model simulates four basic components of the insurance operation—policy production, premium collection, loss and expense incursion. Output is a modified operating statement.

Applications of the simulation model have indicated its value in: (1) structur-

ing system and data analysis, (2) management planning and control, and, (3) sensitivity analysis of various management decision parameters.

SS2A.25. Piecewise Markov Processes in the Theory of Queues, A. KUCZURA.

A piecewise Markov process (PMP) is a discrete-state, continuous-parameter stochastic process which is Markovian over time-segments of random length. It is a generalization of a semi-Markov process, which is constant over these segments.

This concept can be used to analyze composite-input queues. For instance, the number of customers in a GI + M/M/s queue (one with two types of input streams—a Poissonian stream and a GI stream) is a PMP. The distribution of the number of customers in the queue encountered by each type of arrival is obtained from the stationary results of the PMP.

SS2A.26. The Army Pipeline System Study, R. STANLEY LA VALLEE.

This paper describes a systems analysis of the engineer installed part of the Army Bulk Petroleum System. The components examined include the pipeline, pumping stations, storage tanks, and marine terminal. The time frame is 1970-1985. The analysis was broken into two phases. Phase I treats current state-of-the-art systems that could be procured by 1975; Phase II uses technological forecasting and a quasi-dynamic programming approach to choose optimum R & D strategies that would eventually lead to a follow-on system. For Phase I a hierarchy of analytic and simulation models was used to examine components and parameters to minimize the number of combinations that had to be examined.

SS2A.27. An Uncertainty Principle of Modelling, G. ARTHUR MIHRAM.

This paper addresses the capability of operational research methodology to provide realistic formulations, or models, of general systems. The conscientious effort to analyse systems, in detail adequate to deducing meaningful models, is shown to be limited limited by the intrinsic nature of systems as well as man's limitations in the observation process. Incertitudes deriving from these limitations are evaluated in view of the current need for larger, more detailed models which mime systemic behaviour realistically. Methods by which this uncertainty principle can be overcome are discussed; their relationships to alternative techniques for improving the precision of model responses are delineated.

SS2A.28. A General Analysis of Closed Loop Conveyor Systems, E. J. MUTH and S. D. ROBERTS.

An important class of material handling problems involves closed-loop irreversible conveyors, such as bucket conveyors, overhead monorails, trolley conveyors, towveyors, carrousels, suspended-tray conveyors, and tow-line conveyors. Beside their principal function of transporting material these systems are capable of storing material and smoothing out irregularities in the flow of material at loading and unloading stations. This paper presents a general solution to the problem of conveyor design for arbitrary loading and unloading patterns. This solution makes use of a systems engineering approach, whereby the loading of the conveyor system is a response to a forcing function. The system is represented by a difference equation, whose solutions appear naturally in terms of a Fourier series expansion. Solutions for several specific forcing functions are presented graphically.

SS2A.29. Evaluating Heuristics for Vehicle Scheduling, BRIAN O'NEIL.

The vehicle scheduling problem that is considered in this paper consists of finding the minimum number of trucks to satisfy the demand of a known set of customers from a central depot. The trucks are capacity constrianed in time (i.e. they can not travel more than a specified number of hours per day). Several heuristics are developed and compared for assigning the trucks to customers in an attempt to develop "good" solutions. These heuristics are then evaluated against an optimizing algorithm.

The basis for the optimizing algorithm is a branch and bound treatment of the multi-salesman traveling salesman problem with a capacity restriction on the salesmen. The research has shown some reasonable heuristics for practical size problems are available.

SS2A.30. Decision Analysis of the "Influenced Voter" Problem, M. WAYNE PARKER, LARRY G. BROWN and CARL BUTLER.

The practical politician in a highly organized district or precinct must decide whether it is worthwhile to try to influence each eligible voter. Presently, there is indecision on this question, and when it is answered in the affirmative, campaign expense and difficulty may be needlessly increased.

This paper describes a decision theory analysis of the problem, utilizing an original set of natural states transformed by transition probability matrices to a set of secondary states, with the applicable matrix depending on the action taken. A computerized solution is shown using well specified hypothetical data and listing the optimal action for a wide range of voters attitudes.

Considerations for data selection, real world applicability, political realities, and problems for extension to models more realistically applicable are discussed.

SS2A.31. Single Server Queues with Service Time Dependent on the Waiting Time, MORTON J. M. POSNER.

A class of queueing models is discussed in which the service time of a customer at a single server facility is dependent on the amount of time that customer spent queueing for service. A complete investigation is carried out in the particular case of exponential service times with the parameter an almost arbitrary function of the waiting time. The stationary waiting time distribution is investigated for the queue discipline wherein customers are served in order of arrival. This class of model is particularly suited for applications wherein customer or item deterioration occurs during waiting, or where the server wishes to provide a more appropriate level of service to counter the negative effects of customer impatience and loss of goodwill. Some particular applications of this model will also be discussed.

SS2A.32. Another Multistage Sequential Decision Algorithm, D. F. SANDERSON.

An algorithm, which is a revision of Dijkstra's shortest-path algorithm combined with efficient data management, will be presented which frequently is competitive with dynamic programming with respect to both storage size and number of operations performed. Statistical synopses of results of computational experiments will be indicated.

SS2A.33. Decision Analysis and Sensitivity, RICHARD SHACHTMAN.

Major systems problems involving decision-making may often be modeled using the multidisciplinary framework of decision analysis developed by Professor Ronald A. Howard and others. The inherent uncertainty in such problems is not limited to the randomness of the environment but is also present in the decision-maker's subjective estimates of prior distributions. Decisions are sensitive to changes in priors and one is concerned with which priors leave an optimal decision unchanged. An efficient technique is to analytically describe the admissible boundary of the set of decisions in which optimal decisions must occur. An algorithm for generating this boundary is developed and studied. The approach has application to other problems in linear optimization as well.

SS2.34. Optimal Reordering Policies for Substitute Items, ARVIND A. SHAH.

A multiproduct dynamic stochastic inventory system is considered. In this system some products can be used as substitutes for some other products. When ordering, holding, shortage, and substitution costs are linear, the optimal reordering policies are shown to be "simple" under certain conditions on unit costs. Computational results are presented for a two-product case.

SS2A.35. Stadan and Data Relay Satellite Simulation, NORMAN SHUSTERMAN.

A set of computer programs has been developed which can be used to simulate the operation of NASA's Space Satellite Tracking and Data Acquisition Network (STADAN). The simulation consists of two major modules, a Computerized Algorithmic Satellite Scheduler (CASS) and a Generalized Evaluation Model Simulator (GEMS). CASS generates in-view time intervals of satellites over ground stations, and using these "candidate passes," produces a schedule of service times for specific satellites to be serviced by specific ground stations in an attempt to fulfill certain imputted service requirements. GEMS then examines how well STADAN fulfills this schedule in terms of the availability and dependability of different (imputted) complements of equipment at the ground stations. The simulation was recently modified to allow for the introduction of one or more tracking and data relay satellites, which can serve as orbital receiving and command stations.

This paper will describe the simulation and demonstrate its usefulness by presenting the output from several computer runs.

SS2A.36. Multiple-Item Multiple-Source Procurement Policy with Several Warehouses, EDWARD A. SIECIENSKI and P.T. LELE.

A company usually has several warehouses, each of which have several types of storage facilities and therefore various cost characteristics. The items to be stored can be procured from many suppliers with a variety of conditions, such as minimum ordering quantities, price breaks, and pallet sizes. The problem is formulated as a dynamic programming model with an embedded procurement-inventory subproblem. A space utilization factor accounts for the interaction between the inventory levels of many products. The optimal solution provides the warehouse capacity, order quantity, vendor selection, and warehouse allocations to products and minimizes total of rental, handling, inventory and procurement costs.

SS2A.37. The m-Traveling Salesman Problem with Ordered Visits, HELMAN I. STERN, EDGARDO P. RODRIGUEZ and MERLIN L. UTTER.

The m-traveling salesman problem with m disjoint origins is investigated. Assuming a total of n nodes to be visited, each tour consists of n/m nodes selected from ordered subsets of nodes of size m. Each tour is closed in that each salesman returns to that node from which he started. A branch and bound algorithm has been developed using Murty's algorithm for ranking assignments. Upper and lower bounds are successively computed on sub-assignment problems until an *optimal* solution is found. Applications are envisioned for combined mineral aggregate-solid waste truck scheduling and solid waste collection scheduling for large metropolitan regions

SS2A.38. The Continuous Version of Bellman's Stochastic Gold-Mining Process and Optimal Control, JAMES G. TAYLOR.

Over a decade ago R. Bellman formulated the stochastic gold-mining process which involves the tradeoff between risk and return. The version in which decisions are made and implemented continuously over time was originally studied by classical variational methods and knowledge of the discrete-time solution. When this problem is reexamined by the more general approach of modern optimal control theory, new insights are gained into the operation of maximizing return from a resource subject to breakdown or loss. In all, solutions to four versions are developed and contrasted; non-diminishing versus diminishing returns and prescribed duration use versus maximum return for specified risk.

SS2A.39. A New Effect of Probability on Optimal Pricing, G. THOMAS and A. WHINSTON.

This paper presents the development of a new theory of demand which both rationalizes observed behavior and leads to a new theory of pricing. Probability of delivery is introduced as an explicit parameter in a demand function. This requires the

development of a new equilibrium condition in terms of probability and creates a new decision variable for the manager. An example of the new pricing theory is shown by its application to the airline industry.

SS2A.40. Applications of the Relationships Between Decision Tree and Simulation Systems Logic, ROBERT W.L. THOMAS.

The logic flow structure for simulations involving regeneration can be represented in a form very similar to that of decision trees and experience gained in one area can be applied in the other. The relationship is of particular value in designing data storage and elimination techniques for the simulation of physical systems with random regenerating characteristics. A number of modified random walk problems have been solved using these techniques and an important example in the theory of the remote sensing of environmental pollutants is detailed.

SS2A.41. Allocation of Resources, C.J. THORNE.

All managers and administrators have two major decision problems: how to best allocate a given total amount of resources, and what resources will be required to achieve a specified performance. Resource examples are men, money, materials, machines, space, and time. Such management decisions must be made periodically with intervening frequent revision and fast answers to "what if" questions.

A general mathematical theory, problem solutions, and computer program for these two management decision problems is presented. As a further aid to decision, the computer program outputs graphs of the solution versus problem parameter values and non-optimal resource allocations.

SS2A.42. Control of a Two-Customer-Class Interactive Multi-Facility Queuing System, JAMES M. TIEN.

Queuing situations exist where each service facility of a group of parallel non-interactive and/or interactive service facilities has to accomodate two classes of customers, according to whether the customer has an emergency or non-emergency status classification. The emergency customer requires immediate service, if it is available, whereas the non-emergency customer can be controlled and scheduled for service at perhaps a later date. The transient and steady state behavior of both parallel non-interactive and interactive service facilities are investigated, subject to two general types of control of the non-emergency customers.

SS2A.43. Decisions Based on Limited Data, N.S. TZANNES.

The author has recently laid the foundations of a Theory of Prior Probabilities for problems which involve a limited prior data. This theory is based on Shannon's Information Principle and more specifically on "rate distortion theory". A principle is suggested, called the Mutual Information Principle (MIP) which can theoretically pick a prior probability density (or mass) function based on prior available data for the random variable, so that the mutual information between the observed random variable and the underlying one, is minimum. The principle is believed to be valid for both continuous and discrete models and can be used even if the data is obtained with errors. It reduces to E. T. Jaynes' maximum entropy principle when the random variable is discrete, and the data is errorless.

In this paper the theory is applied to a problem of decision making in the field of environmental crisis. The problem deals with the decision on whether to allow the construction of a chemical plant which will use a nearby lake (or land) for its wastes. The problem is carried through for several types of average prior information available to the decision making body.

SS2A.44. Inherent Problems with a Flow Receipt Inventory Model for Intermittent Production Operations, FREDERICK C. WESTON.

A manufacturer who produces one or several products on an intermittent

basis can be easily misled by a popular fixed price, flow receipt inventory model. This paper contends that the inventory manager may be making incorrect decisions if the flow receipt model in question is deemed appropriate and is employed.

This paper attempts to show when and how the popular flow receipt model is erroneous and develops a generalized model to depict the same conditions purported to be represented by the textbook model. The discussion is extended to include the differences between the two models (text *vs.* author) when a quantity discount or price break situation is relevant. This paper should be of interest to inventory managers and managers of intermittent production operations.

SS2A.45. A Program Manager's Dilemma, or How to Balance Your Budget When You Don't Know What Demand Is, DENNIS R. YOUNG.

This paper examines the decisions of a program manager responsible for providing a public service, under a fixed budget and uncertain knowledge of demand. Demand and unit cost are non-decreasing functions of service quality. The manager tries to choose a quality level to minimize his expected loss (based on bureaucratic penalties) associated with an unbalanced budget that can result from having to service demands that fail to match his budget capability. The analysis is useful for considering alternatives for modifying a manager's reward system to bring his behavior closer to societal objectives.

SS2B.1. Path Analysis: A New Approach to Modelling Health Service Delivery Systems, JAMES G. ANDERSON.

This paper presents a model of the health service delivery system serving the state of New Mexico and the method used to construct it. Path analysis has been used to construct a model linking social, economic, and demographic characteristics of New Mexico Counties to characteristics of the health service delivery system and to several measures of health. Path coefficients have been estimated from census data, vital statistics, and communicable disease summaries. The model has been used to predict both direct and indirect effects on the health of New Mexico's population that would result from changes in the composition of the population and from modifications to the present delivery system.

SS2B.2. The Use of Decision Theory in Treatment Selection, GARY M. ANDREW and WILTON H. BUNCH.

The medical profession is frequently faced with the need to make sequential decisions regarding multiple alternatives given information of an informal nature. One such example, the choice of treatment for a closed, transverse, midshaft fracture of a femur, is considered as a first order, discrete parameter Markov chain. A cost was assigned to each transition which allowed calculation of expected costs for each possible treatment decision. The method is sufficiently general to allow application to other situations where discrete states in the disease process may be identified.

SS2B 3. Block and Cyclic Scheduling for Radiologists (Physicians)—Does It Work?, ROBERT C. BANASIK

Recently Riverside Methodist Hospital incorporated a method of block and cyclic scheduling in its Radiology Department. The Block Schedule places Physicians at a certain place at a certain time each day. They cycle through the schedules in a prescribed manner. The results are dramatic. The physicians who believed that another radiologist was necessary to keep up with the work load found themselves with spare time. The 7:00 a.m. to 5:00 p.m. schedule became a 7:00 a.m. to 12 Noon schedule. The Radiology Department which was requesting an increase of five technical people found they needed none and, in fact, might be able to reduce the number of Radiographic Rooms. Most importantly, the patient waiting and service time within the Department was virtually eliminated.

SS2B.4. Primary Health Care Delivery System Simulator, M.A. BAUM.

A generalized primary health care delivery system simulator for urban populations is developed. The simulator combines the macro modelling approach of spatial analysis and the micro modelling approach of the health service/facility utilization models. Multi-facilities are described by their location, services, resources and organizational structure. Patients, described by their location and demand, are allocated to a facility using a modified "gravity" model and processed by the individual services demanded according to the internal organizational structure of the facility. Referral to other facilities is also considered.

SS2B.5 A Car-Following Model Relating Reaction Time and Temporal Headways to Accident Frequency, EDWARD A. BRILL.

This paper deals with a car-following model relating driver reaction time, temporal headways and deceleration response to accident frequency. The central goal is to assess the sensitivity of accident frequency to shifts in the distribution of driver reaction times. This problem basically reduces to that of determining the sensitivity of the probability of "ruin" to changes in the "drift" of the process of cumulative reaction times. This model is particularly relevant to freeway traffic during the rush hour, and to the incidence of rear-end collisions. Numerical examples illustrate the profound effect of reaction-time saving braking devices.

SS2B.6. A Mathematical Programming Approach to Designing an Optimum Health Program Mix, MILTON CHEN and J.W. BUSH.

This paper presents mathematical programming models for designing an optimum program mix in health planning. Output for a health program is defined in terms of function years, or quality adjusted years of life. The numbers of patients in the subgroups of the target population constitute the variable which can be controlled to maximize total function years subject to budget, resource, and patient constraints. Empirical data will be used to demonstrate the usefulness of the models as tools for health planning.

SS2B.7. Optimal Short Term Financing Decisions Under Uncertainty, PETER A. CROSBY.

With the cash requirements over the short term planning horizon being uncertain for a firm with seasonal sales, it is often difficult to determine the minimum cost method of financing these requirements. The short term funds market may be called on in a variety of ways to cover these seasonal needs. Some of the sources of these funds are an unsecured line of credit, term loan, accounts receivable pledging or factoring, and commercial paper. This paper first formulates the cash budget probabilistically over the short term planning horizon, considers the firm's risk preference in choosing period cash requirements, and solves the short term financing problem with a mathematical programming routine.

SS2B.8. Role of the Medical Center in the Community, DONALD F. CUDDIHEE, SR.

This presentation is a refreshing departure from hard data and abounds with concepts that organize an expanding population around its health needs. Shown is a generalized system for delivering programs directed to all stages of disease and one which serves the whole man in his social and environmental problems. This presentation represents the assignment to develop a physical plan but in doing so examines the wellsprings of the client's goals and objectives and the needs of the community in formation. Those in operations research are challenged to order their talents for the realization of a useful product on an interdisciplinary basis and are assisted in the visualization of an environment for organizing a health care delivery subsystem for operational effectiveness.

SS2B 9. An Analysis of the Logistics of Sterile Medical/Surgical Supply and Material Support for Army Field Hospitals, STEPHEN FINEMAN.

This paper presents an analysis of the logistics of supplying and processing sterile medical/surgical supplies and materials for Army field hospitals. Although the analysis focuses on Army field hospitals (60-bed mobile Army surgical hospitals [MASH] and 400-bed evacuation hospitals) it has applicability to other hospitals as well.

The analysis slightly modifies classicial inventory theory to take into consideration the special needs and requirements of Army field hospitals, particularly the need to accommodate peak, or near peak, demand conditions, to allow for the possibility of being "cut off from supplies" and to take into consideration the differing requirements of single-use and multiple-use items.

The information contained in this paper is based on work aided by contract support from the Department of the Army and the U.S. Army Medical Research and Development Command.

SS2B.10. The Grisly Analytics of Death, Disability, and Disbursements, BRIAN E. FORST.

In a large class of decision problems under uncertainty, death, disability, and reductions in wealth enter the analysis as crucial arguments in the utility function. Much of the literature in public health and safety programs, insurance programs, and clinical decision making concerns itself with optimal policy or behavior in the presence of risk in these variables. This paper sets out, primarily, to describe the assumptions which typically underlie these analyses and demonstrate why they may be too restrictive for models which deal with the death, disability, and disbursement variables. An alternative scheme is proposed.

SS2B.11. Branch Office Queue Simulation Model, HARVEY FRANK.

The data processing maintenance market continues to expand, presenting many opportunities and challenges for the service organization. Requirements of improved service at lower costs dictate the use of new techniques to enhance effective utilization of field personnel.

The Branch Office Queue Model is a digital, stochastic simulation of a data processing, multi-product, maintenance environment at the Branch Office level. It directly addresses the resources (i.e. manpower, training and operational procedures i.e. dispatch rules, territory assignments) which most efficiently meet the maintenance requirements of customers.

The model allows the user to study the impact of varying resources on level of service and to synthesize short and long-range alternative decisions for optimization.

SS2B.12. Earnings Per Share and APB Opinion #15: A Simulation Model, GEORGE M. FRANKFURTER and BERTRAND HORWITZ.

APB Opinion #15 defines new guide-lines of calculating earnings per share data in the face of the income statement whenever "residual securities" are present in the firm's capital structure. A new concept, "primary earnings per share," based on common stock equivalents (options and/or conversion obligations as if exercised) is introduced while the "traditional" earnings per share calculation method (based on actual number of shares outstanding) is abolished. In this paper a computerized model is designed to simulate both exogeneous economic factors and endogeneous decision rules in order to show the expectations of the different EPS calculations under various capital structures. A statistical analysis questions the "consistency" and "meaningfulness" of the new concept claimed by the Opinion.

SS2B.13 Automated Medical History Data Processing, R. C. TEGTMEYER.

Existing and proposed national health maintenance programs can place heavy loads on the medical resources of the country. A particular scarce resource in the health delivery system is the available physician time.

A time consuming factor in generating a health profile on a patient is the documenting of the medical history of the patient.

A patient self-administered and automated medical history questionnaire, combined with automated laboratory test results can present the physician with a patient health summary before his appointment. Much of the time usually spent in the traditional patient-physician dialogue is then saved and can be concentrated on the automated test findings.

This paper surveys various operational and proposed methods for automated computerized processing and storing patient medical histories. Advantages and disadvantages of alternate systems will be highlighted. The paper closes with a projection of future trends in the field of medical record keeping practices.

SS2B.14. Health Disorders of the Urban Poor, Spatial Analysis and the Economics of Health Facility Location, PAUL F. GROSS.

The paper describes a three-module health planning model which: *first,* attempts to predict the dynamics of the occurrence of certain health disorders in large urban poverty areas, given a number of socioeconomic and ecological variables; *second,* predicts the demand for certain health facilities in the area (given the pattern of health disorder), and estimates the extent of the unmet health need and the need for new facilities; *third,* estimates the supply of hospital and physician services, in an attempt to evaluate the existence of economies of scale, and thus the size and location of the new facility.

SS2B.15 Operations Research in Hospital Design, RALPH H. CONWAY.

This paper describes the role which operations research can play in the architectural planning of hospitals, with examples from the author's research.

Planning decisions are often done in meetings of architect, administrator and those professionals who use the hospital. Seldom are decisions based on research. Yet, the architecture constrains the functions of the organization. Therefore, logically, the organization should be studied and redesigned if necessary, before the architect begins. His design should be based on such studies. Clearly, operations research should play a role in this process.

This paper describes three studies which were done to develop hospital architectural programs, including the results and acceptance of the researchers and their recommendations. It suggests prospects for the future.

SS2B.16. A Random Vector Payoff Two-Person Game to Study the Cost-Effectiveness of Service Warranty Policies, TIEN-FANG HOU.

A random vector payoff two-person game is proposed as a cost-effectiveness model to study conditions under which a customer should buy a service warranty policy when he purchases such merchandise as a color TV or a telephone. The model also tells how the manufacturer should price his service warranty policy and how he should control the reliability of this product. Money payoffs are the primary factors considered by both the customer and the manufacturer. The effect of customer inconvenience, because of trouble, is also evaluated.

SS2B.17. Cybernetic Modeling of Adaptive Systems, DANIEL HOWLAND.

Cybernetic models may be used to represent complex systems which utilize their resources to achieve specified goals. Although the concepts are general, specific applications present methodological problems. Having identified the information required to answer management questions, models to provide the information can be developed. Modeling starts with the observation and measurement of system bahavior. Functional relationships to explain behavior are then constructed from the data, and computer analysis is used to determine how resources are used to cope with disturbances by maintaining essential variables within limits. The methods will be described and illustrated with reference to health and naval systems.

SS2B.18. Body Thermal Comfort and Linear Programming, FU-TONG HSU.

A mathematical model of an integrated human thermal system which consists of the human thermal system and its external thermal regulation system was formulated. The external system contains a network of cooling tubes which is held in contact with the surface of the skin. The operating variables of the external system are the coolant temperature and its flow rate. The linear programming was employed to optimally control the integrated system under different levels of body activity. The objective of the control is to maintain the temperature of the human body in a state of thermal comfort (thermoneutrality). The results of the study are supported by the experimental data and are proved to be useful for protecting personnel who are often exposed to thermally hostile environments such as steel mill, coal mining, under water, etc., from thermal exhaustion.

SS2B.19. Developing a Management Information System for a National Health Care Grant Program, FRANCIS C. ICHNIOWSKI.

This paper describes, in summary fashion, the extent of the various techniques being employed to cope with the problems facing the administration of a national health care grant program. The effort, currently a year old, began with a task force study which examined existing reporting systems and compared them to current needs. Their outputs became the basis for the plan to develop a comprehensive Management Information System. A centralized data base is being designed and a modular arrangement for development of the total MIS has been chartered. The paper identifies the accomplishments to date and the plans scheduled for future implementation.

SS2B.20 An Analysis of a Health Care Delivery System, ROBERT C KOHBERGER and JAMES MAHERIS.

This paper will analyze the decision to bus patients on a county-wide level into a central clinic (or clinics). The problem is a complex one; it involves routing through a transportation network–bringing patients both to and from the clinic–and a queuing system–the operation of the clinic. A computer simulation approach was used because of this complexity. The actual routing and operation of the clinic is simulated. This simulation will, first, bring about a better understanding of the system. Second, it will provide the framework for optimal decision making on the part of health department officials.

SS2B.21 Estimating Hospital Costs While Controlling Case-Mix Variation, LESTER B. LAVE, JUDITH R. LAVE and LESTER P. SILVERMAN.

Basic economic relationships must be estimated before resource allocation can be improved. Incentive reimbursement for hospitals depends on detailed knowledge of the marginal costs of each case; type, size, and location of hospitals depend on the extent of scale economies. Estimation is complicated by the inherently difficult task of characterizing output for a multiservice firm. Procedures are developed to control for output, including using case-mix measures as explanatory variables, defining aggregate case-mix measures, and grouping hospitals with respect to output. Results are presented for Pennsylvania hospitals.

SS2B.22 The Iowa Redistricting System, JOHN M. LIITTSCHWAGER.

A system for legislative districting by computer is described. This system comprises programs useful in data preparation, district generation, and report preparation. The system was extensively used in 1971 in Iowa legislative and Congressional redistricting activities. Earlier versions of the system were used in 1967 and 1969 state redistricting problems.

Recent developments in the system have been oriented toward solving relatively large districting problems. For example, the basic data set for the Iowa legislative problem was comprised of 3695 population regions, primarily 1970 Iowa census enumeration districts.

SS2B.23. An Evaluation of the Use of Some Library Programs in Operations Research, JOEL H. LUBIN.

Economic, technical, 'political' and other considerations in the use of 'canned' or library programs; including batch, remote batch and time sharing programs from several major hardware and software vendors are discussed both qualitatively and quantitatively. The sources and selection processes for the programs will clearly be identified. Major application areas in O.R., input constraints, and total user costs will be the primary criteria. Pitfalls in the use of canned programs along with the potential diseconomies of the 'not invented here' philosophy will be discussed.

SS2B.24 Medium and Short Term Scheduling of Nursing Staff, CHRISTOPH MAIER-ROTHE and HARRY B. WOLFE.

Nursing staff represents the largest single cost factor in hospitals. An effective allocation of available nursing staff to patient care requirements is therefore an important tool in controlling the cost of health care. An allocation procedure is presented which consists of two parts: (i) a medium term cyclical schedule consistent with a hospital's personnel policies, average staffing requirements and employee preferences, and (ii) a short term adjustment of staffing according to an index of the latest patient care requirements. The procedure was successfully implemented in a major hospital and improved nursing staff allocation. The individual steps of the implementation will be discussed.

SS2B.25. A Study of a Hospital Admissions System, L. WILLIAM MILLER, H.M. ALEXANDER, Sr., F.F. BARAN, Jr. and D.C. CARD.

This paper reports on a study of hospital admissions problems. Admissions problems in terms of: 1) adequate medical records, 2) waiting time for patients, 3) scheduling of facilities are among a hospital's major problems. The following problems were investigated from the viewpoint of the patient as well as the hospital:

1. Needs analysis on number of patients expected from the community and typical illnesses,
2. Actual admissions data to derive a math model to determine the number of servers and physicians,
3. Considerations of costing, improved records, physical and psychological factors,
4. Alternative solutions using satellite centers located in the patients' neighborhood to preprocess forms by remote terminals.

The implementation results by the hospital are also reported.

SS2B.26 Control of Blood Utilization Performance by Hospitals, C. CARL PEGELS, ANDREW E. JELMERT, KENNETH E. KENDALL, JOHN P. SEAGLE and EDWARD L. WALLACE.

Effective blood utilization within a regional blood system requires close control over blood utilization performance within associated hospitals. Performance criteria for an effective regional blood system are discussed, developed and translated into desired measures of hospital performance; methods of approximating desired measures of hospital performance are proposed and analyzed for their motivational implications; and organization and operation of the supporting peer review process is analyzed. The system is now being implemented in a large regional blood system.

SS2B.27 Sharpe's Diagonal Model: Unknown Parameters and Stochastic Security Index, HERBERT E. PHILLIPS and GEORGE M. FRANKFURTER.

Sharpe (1963), by assuming that security returns can be related to some basic index, uses a regression structure to describe a model that reduces the necessary input information, while not assuming away the existence of interrelationships among security returns. Once the parameters of his diagonal model have been specified, all the inputs required for the standard Markowitz model can be derived. The stochastic nature

of the index and problems of estimating the required parameters for the diagonal model are ignored, however. Estimates of the variances and covariances will be affected by the distribution of the index, and by any error (which is not independent of uncertainty about the index) in estimating the required regression coefficients. It will be shown that unless the distribution of the security index is known, Sharpe's algorithm cannot be substituted for the standard MARKOWITZthe standard Markowitz model whether or not the variance-covariance matrix is known.

SS2B.28 Optimal Issuance of Whole Blood From a Hospital Blood Bank, WILLIAM P. PIERSKALLA.

One of the major costs in a hospital blood inventory is the outdating of whole blood. A model is presented which minimizes the expected number of outdates. It is shown that the decision space (which is a convex polyhedral set) is represented by a unimodular constraint matrix. Thus with a linear objective function the optimum solution is obtained via linear programming. These results are extended to obtain the optimal resupply policies also. Since the demand is a discrete random variable the entire problem becomes a stochastic linear program. Efficient algorithms capitalizing on the structure are presented.

SS2B.29 Managematics: The Concept and Its Application, JACK B. ReVELLE.

MANAGEMATICS is both an integration and a pragmatic extension of previous behavioral research. It provides a new, operations research-oriented management tool which consists of a series of three-dimensional predictive models for fifteen identifiable attributes of industrial organizations. The dimensions of each model are: styles of management; levels of management; and the vector value of a specific attribute. The linear analyses of the vector values within the tripartite spatial models for the most critical attributes provide a quantitive means for the determination of an overall preferred style of management for specific industrial organizations.

SS2B.30 An Evaluation Model for an Alcohol Safety Action Program, ROBERT T. RILEY and THOMAS A. WILLIAMS.

When funding an urban Alcohol Safety Action Program, the Department of Transportation requires that a comprehensive, impartial evaluation of the program be conducted on a continuing basis. Since these are complex programs comprised of a number of simultaneous and dissimilar subprograms, structuring an evaluation which will isolate and measure the impact of specific components is a significant measurement problem. This paper describes the evaluation model developed for the Cincinnati program under the direction of the authors. Included are the basic evaluation model, the information system developed for ongoing monitoring, and the statistical and survey techniques used for data acquisition.

SS2B.31 Economies of Scale in Medical Practice, RICHARD M. SCHEFFLER.

This paper deals with methods which can be used to test for the existence of economies of scale in medical groups. Different functional forms of production functions are tested using micro-data collected from medical groups in North Carolina. The labor inputs include physicians, ancillary and clerical personnel. Special attention is to be paid to the substitution ratios between these labor inputs. Inferences are also made concerning the optimal size of a medical group.

SS2B.32 TOPS/Schedule Increases Profit: A Real Construction-Industry Example, ROBERT J. SCHRIER and ELIZABETH A. TILLEY.

TOPS/Schedule is a computer program to handle the cost/schedule trade-off in an incentive environment. TOPS/Schedule is part of the TOPS system for maximizing profit on a project by optimally using contractual and internally formulated incentives for cost, performance and schedule. For a boiler erection project, TOPS/Schedule produced an optimal schedule which increased profit by approximately 8 percent over the nominal operating schedule. This paper will show the concepts involved in the optimiza-

tion process for the cost/schedule trade-off, and illustrate the results with the boiler erection project data. Particularly interesting is the formulation of incentives concerning such things as weather delays, labor escalation, and move-out costs.

SS2B.33 A Model for the Allocation of Ambulatory Health Care Centers in a Metropolitan Area, LARRY SHUMAN and C. PATRICK HARDWICK.

An algorithm is developed for the ordered allocation of a network of ambulatory health care centers (Health Maintenance Organizations) throughout a designated metropolitan health service area. The model makes use of present patient utilization patternsn, physician office locations, physician specialties, hospital locations, available hospital facilities and services, projected medical and health care demands, natural boundaries and local transportation and road systems in selecting optimal site locations. The model is applicable for areawide community health care planning agencies, prepaid group practice programs or health maintenance organizations. Results will be presented for the Pittsburgh metropolitan area.

SS2B.34 Effectiveness of Airmobile Services in Health Care Systems, AMAR J. SINGH.

There are many uses of helicopters in the delivery of medical services. Some of the functions performed by helicopters are; (1) Delivery of emergency cases to hospitals, (2) Transportation of highly skilled medical staff from one hospital to another, and (3) Provision of a distribution service to convey samples to and from a centralized laboratory. This paper analyses the utility of helicopters in the above mentioned services. The aim is to estimate the value of helicopters in combating the ever-rising cost of medical service, and to investigate ways of eliminating the shortage of highly skilled medical professionals by making them more productive.

To justify the use of helicopters as an integral part of the health delivery system in an urban area, it is necessary to show that the benefits (greater productivity of medical personnel, better use of facilities,) ultimately result in an improved health status of the population served. Moreover, it is desirable that these benefits outweigh the extra cost of a similar function performed by more conventional transportation systems. A helicopter transportation system which is not affected by congested peak time traffic can provide the reliable and predictable service. It can also take over from ground ambulances by providing guaranteed quick response to emergency calls in these congested areas.

SS2B.35 Technology and Health: Some Thoughts on Computer-Based Hospital Information Systems, DAVID H. STIMSON.

The broad impact of science and technology on the health field has had far reaching consequences--some good, some bad. Computer-based hospital information systems represent one important and growing use of technology in the health field. A summary of what has been learned during the past decade about such systems is followed by several suggestions on how organization theory and information science could be used to aid in further development of hospital information systems. What consequences these computer-based systems may have for the operations of hospitals is explored.

SS2B.36 An LP Model for Estimating Recreation Tours on a National Forest Transportation Network, EDWARD C. SULLIVAN.

An LP has been formulated to estimate the future volumes of recreation "tours" that will occur on a National Forest's road or trail network. "Tours" are defined as trips made principally for the sake of the travel experience itself, such as sightseeing, hiking, and trailbike riding. Trips of this type are characterized by their lack of well defined destinations, trips being attracted instead to sizeable portions of the transportation network itself.

The most unusual aspect of the formulation is the set of constraints that act to maintain conservation of flow without eliminating any theoretically acceptable touring

behavior; a difficult problem, since a given tour may turn back towards its origin at any point on the network.

The model was developed for the U.S. Forest Service as an aid to resource management planning.

SS2B.37 Performance Attributes for the Radiographic Facilities Location-Allocation Problem, GERALD J. THUESEN, WILLIAM G. SULLIVAN.

Planning decisions related to the function, number and location of radiographic facilities in the master plan of a large teaching hospital are based on cost and performance considerations. In this paper an approach is presented for establishing performance attributes and measures for the radiographic location-allocation problem. Attention is given to the influence of institutional goals and "pressure groups" on the process of articulating attributes employed to judge the feasibility of proposed departmental designs. Results of the research include a hierarchy of criteria by which alternatives under study may be evaluated quantitatively.

SS2B.38 Health System Ecology: An Interactive Model, ILAN VERTINSKY, JOHN MILSUM, DEAN UYENO and HART WILL.

The Health Care Simulation Model is part of a microcosmic model of the Greater Vancouver Region. This Health sub-model is characterized by interactive capabilities in order to provide operational indicators for the impact of changes in other sub-models. Morbidity prevalence levels in the Health sub-model are modified by outputs from the Population, Pollution and Transportation sub-models. These are modified by outputs from the Human Ecology sub-model to generate demands for health services, which counteract environmental and social stress. The health resources and demands are matched to measure the extent of these remedial actions. Required resources are fed as inputs to the Economic sub-model which in turn affects life style and activities generated in the Human Ecology submodel.

SS2B.39 Investment Feasibility Analysis, RICHARD B. WILL.

This simplifying methodology, for analyzing the feasibility of investments in income property, is based on aggregation of after-tax discounted cash flows. Under certain assumptions, the annual rental required to achieve a fixed rate of return can be shown to be a linear function of land cost, improvements cost, borrowing, and initial maintenance and property tax expenses. The coefficients are a function of after-tax rate of return, income tax bracket, occupany period, inflation rate, improvements depreciation period and rate, and loan period and interest rate. By modifying the model, so as to input rental and calculate initial costs, a property appraisal results.

SS2B.40 Queueing Model for a Community Health Center, ELIZABETH H. YEN.

The operations pattern of a community health center is described by a queueing model with five phases and five kinds of patients receiving different kinds of services. services.

Instead of finding equilibrium conditions analytically, a realistic time truncated model is developed. By computer simulation, various parameters of interest can be estimated, e.g. average waiting time for all patients or for different kinds of patients; average cost per patient; average service time and idle time for each server.

Also studied are the effects on waiting time and service time, optimal scheduling plan, alternative arrangement of service phases, and allocation of resources on various phases.

SS3A.1. A Bounding Minimization Problem for Primal Integer Programming, LARRY R. ARNOLD and MANDELL MORE.

Computational experience with primal integer programming algorithms indicates that the optimal value of the objective function may be obtained in a few iterations; but a large number of additional iterations may be required to establish op-

timality. An alternative proof of optimality is thus needed. This paper describes an algorithm for obtaining an upper bound on the optimal objective function (such an alternative). This bound is based upon the best bound obtainable from dual solutions to a class of related linear programs. Computational experience concerning the impact of this bounding technique on the efficiency of a primal algorithm is also reported.

SS3A.2. Purchasing Priorities in Queues, K. R. BALACHANDRAN.

A class of queueing problems is introduced in which each customer can purchase preferential treatment by making a *payment.* Each customer is assumed to select his payment so as to minimize his own expected cost, without regard for global considerations. A *payment policy* determines a customer's payment as a function of the information available. A payment policy is said to be *stable* if no one customer can reduce his expected cost by deviating from it, provided that all other customers follow it. The existence of stable payment policies which are not globally optimal is demonstrated in examples based on the M/M/1 queue.

SS3A.3. R&D Budgeting Allocation For New Product Development, WARREN BALINSKY, MELVIN BROWN, DONALD FRIEDEL, MILTON SCHOEMAN.

When budgeting for new product research and development, firms are frequently confronted with deciding how to develop the research capability required by the project. On the one hand, it may be feasible to utilize already existing talent and facilities. On the other hand, research facilities (companies) other than its own may be available for acquisition and may already possess the capability demanded. The decision is whether to perform the necessary research in-house or to acquire available research companies with the required capabilities.

Three mathematical models are developed for aiding in this decision, each of increasing complexity and leading, finally, to the case of arbitrary numbers of potential products and available companies. Solutions are developed by means of mathematical programming considerations and techniques.

A number of extensions are formulated for future study.

SS3A.4. Development of a Methodology for Evaluating Visual Clarity Information Previews in Driving, VIVEK D. BHISE and THOMAS H. ROCKWELL.

This paper presents a methodology for evaluating clarity of visual information at different regions in a driver's visual environment. The methodology centers around development of a measure called "an index of clarity," which is evaluated by recording driver eye movement data in actual driving situations and relating the spatial and temporal characteristics of the movements of the driver's visual axis to his visual acuity in foveal and extra-foveal vision. The paper describes a computer program, ICEVEW, which maps the probability functions of clarity over different positions in relation to highway geometry. The paper also discusses preview weighting functions obtained from the data under different driving situations.

SS3A.5. Capital Budgeting and Sequencing of Projects with a Probabilistic Objective Function and Constraints on Risk, C. RALPH BLACKBURN,II, DONALD R. WOOD, JR., J. LEWIS ROBERTSON.

A capital budgeting model will be presented in which optimality depends upon sequencing in time as well as selection of projects. The objective function is probabilistic in nature such that the coefficient for a particular variable depends upon all variables in solution which are scheduled earlier in time. Constraints are included on profit growth and physical attributes of the variables as well as chance constraints on the risk of exceeding the budget in each subinterval of the budget period. Computational experience with a special purpose multiple-choice algorithm will be discussed.

SS3A.6. A Generalized Dynamic Programming Algorithm, DAVID B. BROWN and MITCHELL OLSZEWSKI.

The separation of the optimization algorithm from the system model is stressed as a concept for organizing a dynamic programming approach to system optimization. The generalized dynamic programming algorithm is presented thus freeing the analyst to concentrate on modeling his system. A flow chart and a FORTRAN program are provided to explain the algorithm along with a discussion of the interface between the main program and the subroutines which model the system. The generalized algorithm is further illustrated by its application to the classical knapsack problem and to finding optimal designs for steam power stations.

SS3A.7. Queues With Service in Random Order, GRACE M. CARTER, ROBERT B. COOPER.

We consider two models, the GI/M/s queue and the M/G1 queue, in which waiting customers are served in random order. For each model we derive expressions for the calculation of the stationary waiting time distribution function. Our methods differ from those of previous authors in that we do not use transforms, and consequently our results may be better suited for calculation. We illustrate our methods by deriving previously known results for the M/Ms and M/D/1 random service queues, and by making sample calculations for the $M/E_k/1$ random service queue for various values of the utilization factor and the index k.

SS3A.8. A Simulation Model to Develop Spares Inventory Aboard an Aircraft Carrier, SAMUEL E. CLOPPER, JR.

This paper addresses the problem of defining a spares inventory which would provide adequate support for an airborne radar system aboard a remote based aircraft carrier. A simulation model is discussed which relates reliability, maintainability, scheduling, and repair philosophy to repairable assembly pool levels and replaceable sub-assembly inventory levels. The application of this model to provide information as to adequate spares for a desired level of operation is discussed and the basis for a cost-effectiveness study is explored.

SS3A.9. A Two-Product Production-Inventory Model With Either-Or Constraints, THOMAS B. CRABILL.

This paper deals with an n period two product deterministic inventory model of the Wagner-Whitin type. It is assumed that only one product can be produced in a single period. This results in an integer programming problem which can be recast as a network problem. This leads to simplification of the solution procedure. Planning horizon results and extensions to the general many product model are discussed.

SS3A.10. More on Stochastic Single Commodity Network Flow, J. W. CRAWFORD.

The extended flow-state formulation of the stochastic single commodity network flow problem is discussed. Two measures of stochastic network flow performance are considered. The use of the extended flow-state objective function to achieve these and some economic measures of network flow performance is presented. Some results relative to costs and revenues of stochastic single commodity flow and network sizing are summarized.

SS3A.11. A Heuristic for the Multi-product Single Machine Scheduling Problem, C. LOREN DOLL.

The purpose of this paper is to present a heuristic which develops a low cost production schedule for several products through a single machine. The problem is constrained to be feasible (i.e., no products produced simultaneously) and to meet all demands. The traditional solution requires production of each product with the same frequency. The heuristic presented here allows production of some products more frequently than others. Computational experience indicates costs produced by this heuristic

are up to 32% less than the traditional solution and 10% less than other good heuristics that allow variables frequency of production.

SS3A.12. Sensitivity Analysis for Statical and Dynamic Leontief Models, K. ENT, J. GETSCHMAN, V. SELMAN.

Many models have been investigated for use in the Navy Programming, Budgeting and Resource Control. Of particular interest for a long range analytical model is an input-output technique of the variety developed by Professor Leontief for the interrelationships among sections of the national economy. This effort investigates the applicability of sensitivity and parametric analysis to changes in budget, demand, and support functions for Naval Operations. The techniques of Linear Programming are utilized for perturbations in both statical and dynamic Leontief models as applied to Naval planning. Several examples are presented and their interdisciplinary extensions to system sciences discussed.

SS3A.13. Quasi-Convex and Pseudo-Convex Functions on Solid Convex Sets, JACQUES A. FERLAND.

We determine two maximal domains of quasi-convexity (pseudo-convexity) for a quadratic form whose matrix D has exactly one negative eigenvalue, and conversely, we show that if a quadratic form is quasi-convex (pseudo-convex) on a solid convex set, then the matrix D has exactly one negative eigenvalue and the solid convex set is contained in one of the maximal domains. Analogous results hold for quadratic functions under the additional condition that the set of vectors where the gradient vanishes is nonempty. In the last part of this paper, we analyze twice continuously differentiable functions.

SS.3A.14.A System for Information Retrieval and Analysis for College Administration, EDWIN C. FOUDRIAT, JOSEPH E. MATAR.

The college operations analysis program at Marquette University has been designed for program analysis and planning at the lowest administrative level, the department and college office, and for the smaller schools without access to large sophisticated computational equipment. Data consists of curriculum, faculty/staff research, and student population. Output consists of enrollment, faculty/staff utilization, course costs, and research activities. The capability exists for administrators to have easy access to data so that each is capable of obtaining additional output information most suitable to his program.

The report will present the program concepts for data storage and retrieval utilization of data, program concepts for information output, and methods for collection of initial data from various university sources

SS3A.15. Randomized Solutions for Stochastic Mathematical Programming Problems, STAN FROMOVITZ and CHAIHO KIM.

By allowing the optimal solution to be randomized we have developed a new formulation of the traditional stochastic programming problem previously developed by Charnes, Madansky and others. Our formulation is in many ways very different from previous work in stochastic programming and it helps to clarify the relationship between chance-constraints as developed by Charnes, other stochastic programming methods and game theory. We also study the computational problems, economic interpretation and practical significance of our formulation.

SS3A.16. The Use of Continuous Simulation Languages in the Teaching of Operations Research, ROBERT G. SARGENT.

This paper describes the use of continuous simulation languages to demonstrate, clarify, and to reinforce concepts presented in the classroom and for solving various types of operations research problems. Example: students using an interactive

computer to explore the transient and steady state behavior of a continuous inventory and production control model under different decision rules.

SS3A.17. A Spare Machine Problem, D. P. HEYMAN.

This talk considers a two-channel service system, where each channel is restricted to have an exponentially distributed service time (possibly with different rates), and the arrivals form a Poisson process. One server is always turned on; the other, the "spare machine," can be turned on and off at arbitrary times. Using a dynamic programming formulation of the decision process, we show that the stationary optimal policy for undiscounted costs has the form: Turn the spare machine on when n customers are present, and turn it off when m customers are in the system with $m<n$. We derive equations for finding the optimal value of m and n when service interruptions are prohibited; then we consider queue disciplines where customers may be switched, without delay or cost, from one server to the other.

SS3A.18. Minimal Disconnecting Sets in Directed Multi-Commodity Networks, JOHN J. JARVIS.

The problem of finding minimal disconnecting sets for multi-commodity directed networks may be solved using an arc-path formulation and Gomory's all-integer programming algorithm. However, the number of network constraints may be astronomical for even moderately sized networks. This paper develops a finite algorithm similar to Gomory's but requiring no more than m rows in the tableau, where m is the number of arcs in the network.

SS3A.19. Revenue-Determined Adjustment Intervals, WILLIAM J. KENNEDY, JR.

A probability distribution function is developed to describe the values of a dimension within a production lot, where the dimension is produced by an adjustable manufacturing process. In the manufacturing process, the dimension is assumed to have its initial value until a disruptive event occurs, after which it is assumed to change as a continuous increasing differentiable function of time until the occurrence of an adjustment. An adjustment causes the produced dimension to take on its initial value again, and the cycle repeats itself. The net revenue to be maximized is defined as the difference between a convex pricing function of the produced dimension and a linear function of the number of adjustments. A simple search technique is described for obtaining the optimum time between adjustments.

SS3A.20. The Application of Mixed-Integer Programming to the Analysis of Letter Processing Systems, MATT LIND.

The application of mixed-integer programming to letter processing systems promises to be a valuable new tool for Post Office planning and research. Unlike simulation techniques in which minimum cost mail processing systems can only be approximated on a trial-and-error basis, the analysis of letter mail processing systems with mixed-integer programming can lead directly to minimum cost systems, including not only the minimum cost man/machine configuration, but the best mail routing scheme as well. This paper describes the application of mixed-integer programming to an idealized letter sorting system.

SS3A.21. On Applications of the Root Locus Method in Operations, E.J. MUTH and B.D. SIVAZLIAN.

The root locus method is used routinely by systems engineers to analyze the stability of control systems. This paper shows application of root locus method to problems in several areas of Operations Research. Exact and approximate solutions to complex problems in inventory, queueing, and reliability are frequently obtained as Laplace transforms. The root locus technique will yield information on the nature of such solutions without the need for explicit inversion. Two specific examples are given: one

arises in the solution of a multi-commodity inventory problem, the other one arises in the solution of an M/D/s queueing system.

SS3A.22. Response-Variance Tradeoffs in Adaptive Forecasting, JOHN O. McCLAIN and JOSEPH THOMAS.

This paper centers on what happens to an exponential smoothing forecasting system when the smoothing parameters are changed. Sufficient conditions are given under which several proposed models will give numerically identical results, and a surprising symmetry is noted between the smoothing constants for the smoothed average and the smoothed trend. These results are used in an analytical study of the tradeoff between responsiveness and variance, in which some dominant choices emerge. A short discussion of behavior is given when the hypothesized underlying model of the time series is invalid.

SS3A.23. Optimum Equipment Layout, FARROKH NEGHABAT.

The problem of locating interconnected physical facilities in a three-dimensional space is formulated as an optimization model. The decision variables are the coordinates of the centroid of the contact area of each facility. The objective is to minimize the overall cost of interconnections while satisfying a set of inequality constraints such as: specific requirements on the relative positions between facilities, limiting conductor lengths, etc. The interconnections are expressed in terms of rectangular distances.

SS3A.24. A Stratified Bid Model, TURGUT M. OZAN and GERALD A. BIASIOLLI.

This model proceeds along the concepts of Friedman's bid model and introduces two basic improvements. In Friedman's model the average bid concept neglects to discriminate between bid price levels. Additionally, it requires data with known probability distribution. In the stratified bid model, the ratio of bid-price-to-cost estimate is formed. These data are, then, stratified in groups of ascending order, in an attempt to relate each strata to its probability of winning a bid. Also, the stratified bid model is constructed on a distribution free basis.

The use of the model is tested on bid price data of eleven projects obtained from a construction company.

SS3A.25. Dynamic Programming for Efficient Tree Utilization, STELIOS PNEVMATICOS and STUART H. MANN.

An important approach to the increased efficiency of forest use is through a more economical utilization of trees after they are felled. We have considered the problem of cutting the trees into logs (bucking) after they have been felled. Dynamic programming is used as the method for optimization. The mathematical model is presented along with an example of the solution procedure. It is suggested that the solution can be implemented through the use of previously generated tables or numerically controlled machine saws.

SS3A.26. An Optimal Procedure for Step-Wise MAD Regression Analysis, GARY M. ROODMAN.

The last several years have seen an increasing interest in mean absolute deviation (MAD) regression analysis. This paper develops a procedure for determining the best k regressors according to the MAD criterion from among a set of $m \geqslant k$ regressors. The procedure under study employs a branch and bound algorithm to solve an integer programming formulation of the problem. A byproduct of the analysis is the ability to do what is generally called sequential step-wise regression in the context of the traditional least-squares method.

SS3A.27. An Arc Elimination Algorithm for the Exact Solution of the Symmetric Traveling Salesman Problem, NORMAN P. SALZ.

An original nonnegative matrix of the symmetric traveling salesman problem is transcribed to a matrix of minimum nonnegative costs whose hamiltonian circuit solution provides a possibily acyclic solution under the original matrix from the arc-to-path correspondence.

The algorithm incorporates ambiguity elimination and an ordering scheme that facilitates arc elimination. Information cumulates as we cycle through the remainder set of arcs until no further information is adduced. At this point the problem under T is solved or a terminating routine solves the problem.

SS3A.28. An Integer Programming Approach to the Reduction of Auditing Cost Constrained by Statistical Precision, WILLIAM G. SCOTT and J. PHILIP KILKEARY.

Given a multi-site organization where the sites can be stratified on the basis of asset value, the cost of performing an audit can be expressed as a function of the number of sites audited and the cost of an audit within each stratum. This paper describes a model which combines integer programming and statistics in an interdisciplinary approach to minimizing audit costs. Constraints insure that a specified percentage of total assets and number of sites are examined and that specified statistical precision and confidence will be achieved. The model has general application to stratified sampling where cost to sample can be established for each stratum.

SS3A.29. A Simplex-Like Algorithm for the Modular Design Problem, T. SHAFTEL and G.L. THOMPSON.

This paper derives an efficient solution procedure to the continuous version of the Evans modular design problem. The Kuhn-Tucker conditions are used to derive a dual problem which can be solved easily and whose dual variables indicate which equations should be tight. The technique retains a tree basic solution throughout so that fast solution routines can be employed which are very similar to those for transportation problems. Because of these analogies, the authors predict the solution of transportation size problems with only moderately increased computer time.

SS3A.30. A Predictive-Control Approach to Conversion Planning, HARRY M. STRONG.

Industry, as well as Government agencies, are faced with the problems of ADP conversion and frequently engaged in computer selection and implementation activities. One activity, however, that is often neglected is the process of anticipating when the level of service to the user will be inadequate. Conventional planning derived from demand forecasts is sometimes undertaken but more often, political, status and entrepreneurial factors heavily affect this process.

This paper draws from the disciplines of cybernetics, quality control and forecasting technology to evolve a predictive-control approach to ADP conversion. The paper develops an anticipatory strategy for the organization of information needed by the decion maker in the conversion planning process.

SS3A.31. Linear Multiobjective Programming, P. L. YU and M. ZELENY.

In real life, decision making often involves more than just one objective. Here we consider a set of optimization problems which have l linear objective functions and a feasible set defined by m linear inequalities. Our main concern is to find all undominated solutions (with respect to the l objectives) in the feasible set. We explore two different algorithms: one is based on a decomposition procedure on a parametric space, the other is a direct search for undominated extreme points in the feasible set. Theorems, examples and computational results of the algorithms are given.

SS3A.32. An Evaluation of a Scheduling Algorithm Used in an Experimental Limited Purpose Time Sharing Computer System, HAROLD A. ANDERSON, JR., ROBERT G. SARGENT.

The efficiency of a foreground–background scheduling algorithm used in an

experimental APL/360 time sharing system is evaluated by analyzing recorded event traces (data) collected over a one month period. The computer demands were found to be heterogeneous and have been classified into five categories. This has enabled the evaluation to be performed for different system loads.

SS3A.33. Applying Computer Analysis Programs to New Areas, JAMES C. BOWERS and DAVID B. GOODRICH.

Most engineering automatic computer analysis programs were originally designed to aid the elctronics engineer in working with passive and solid-state circuits. Programs such as ECAP, NET I, CIRCUS and SCEPTRE have found much application in the last five years by design and analysis engineers working in the electronics field.

Last year the first named writer published a book which extended the SCEPTRE program from the electronics field to the fields of automatic control and to all other non-electrical engineering disciplines. This has been successful in broadening a powerful program to other areas with a minimum of effort.

Since that effort, the writers have been pursuing a further broadening of scope. By taking advantage of the many convenient and automatic features of the SCEPTRE program, problems have successfully been run to aid in the analysis of water pollution in the Tampa Bay, and other problems have been run which proved quite useful in studying the transfer function of the human body. The advantage of extending the SCEPTRE program into these areas is that the program is user oriented, totally free format, and requires no knowledge of FORTRAN or other Computer languages. In fact the researcher can be taught the SCEPTRE format in a very short time with no previous background required and yet the program offers a degree of sophistication and power than even the most knowledgeable programmer would have great difficulty in duplicating.

This paper will discuss the SCEPTRE program format, and then by using a variety of actual examples, show the potential in utilizing this approach in other fields. Comparisons will be illustrated to show how this approach improves over some of the present methods.

SS3A.34. Systems-Affected Unique Single Sampling Plans For Multistage Manufacturing Connected-Unit Situation, SEDAT SAMI ERCAN.

This paper investigates the integrated systems approach for Multistage Manufacturing Connected-Unit Situation. It considers and illustrates the interrelation between incoming quality limit, manufacturing quality level in each stage of production, and outgoing quality limit. It also formulates a mathematical model for the situation and solves it analytically through the use of Lagrangian form of discrete optimization. It restricts itself to the situation where single sampling plan's parameters are unique for the system considered.

SS3A.35. Implementation of a Modified Parametric Decomposition Algorithm: Computational Experience, ARUN K. GUPTA.

A variation of the parametric decomposition algorithm will be presented from the point of view of implementation into a mathematical programming system. Modifications were introduced to simplify implementation and improve efficiency. Computational experience on the performance of this algorithm will be presented and compared to that of the Dantzig Wolf decomposition.

SS3A.36. A Common-Denominator Methodology For General Systems Modeling, J.C. O'BRIEN.

Multidisciplinary systems design requires unified performance model. of entire systems. Differences in scientific terminology have impeded integrated solutions of overall systems behavior. Considerable improvement in achieving holistic models is possible by using universal quantifiable parameters—e.g., probability, energy, mass, time,

information and spatial dimension—to place measurable physical variables in a common analytical language.

Quantitative modeling of subsystem interaction requires also coupling and conservation laws, which can be derived from well-known theories. One combination of parameters, energy and information, which is universally present, permits network simulation of performance flow with high efficiency. An example of a model of this type will be given.

SS3A.37. A System of Systems, FEDERICO FRISCHKNECHT.

SYSTEMS. Axiomatic definition. EMPIRICAL SYSTEMS. States and processes. FORMAL SYSTEMS. Mapping. Symbols and relations. ELEMENTARY SYSTEMS. One operation. Static and dynamic definition. Classification: numerical and symbolic systems. COMPOSITE SYSTEMS. Several operations. Static definition. Classification: Analytical and logical systems. Dynamic (operational) definition. Formulas or tables and flow-charts. Classification: Servomechanisms and automata. COMPLEX SYSTEMS. Several related composite systems. Internal stability (near decomposability) HIERARCHICAL SYSTEMS. Several related sets of systems. Quasi order relation. Level.

SS3B.1. A Mathematical Programming Model To Optimize the Teaching-Learning Process: The Network Model, MARIA R. BELGARD and LEO Y. MIN.

This paper introduces a T-L network model, which is an operations research approach, to optimize the learning process. The T-L network model, unlike dynamic or control theory models, allows the computer to react to the responses of a learner in seconds or less. The learning task is composed of teaching-learning elements which are sequenced according to the objective criterion function to yield an optimal path. A student's flow through the learning process is controlled by the T-L Element Increment Loop and by the Optimal Path Updating Loop.

An optimal path has two types of cost coefficients, i.e., expenses and achievement associated with it. The T-L network model, therefore, has two objective criterion functions. For the optimization of the T-L network model a mathematical programming model of 'assignment problem' type is developed and for its solution the 'direct solution method' is chosen. Since the mathematical programming model deals with a single objective criterion function the Averaging Method and the Constraint Addition Method are proposed, which combine the two objective criterion functions. For this purpose a theorem is constructed and proven which states that no single optimal solution can be found unless the two optimal solutions are combined according to either of the above methods. Through this T-L network model, overall scientific optimization of the learning process for the individual student becomes a reality.

SS3B.2. An Economic Model For Planning Strategic Mobility Posture, G. BENNINGTON, L. GSELLMAN and S. LUBORE.

This paper describes a linear programming model used to perform cost-effectiveness analysis to determine the requirements for Military Strategic Mobility resources. Expenditures for three classes of economic alternatives are considered: purchase of transportation resources, pre-positioning of material, and augmentation of port facilities. For a given investment level the mix of economic alternatives is determined which maximizes the effectiveness of the resultant transportation system. By repeating the analysis for different levels of investment, a cost-effectiveness tradeoff curve can be developed.

SS3B.3. Generalized Expressions for the Minimum Time Interval Between Consecutive Arrivals at an Idealized Railway Station, DIETRICH R. BERGMANN.

This paper presents recently derived solutions for the minimum time interval between successive arrivals at a station in a railway system. Seven independent variables are identified and the problem is formulated mathematically. A sequence of lemmas and theorems leads to the derivation of four expressions for the minimum time interval. The

solutions are then compared to less general previous results and applied in the development of conclusions regarding the operational control and design of vehicles.

SS3B.4. Resource Allocation and Scheduling of Projects Under Uncertainty, JOHN M. BURT, JR.

This paper is concerned with resource allocation and control of projects composed of activities whose individual processing times are random variables. When the predecessors of a given activity are completed, the decision maker (i.e., project manager) must select a starting time and resource allocation for the upcoming activity so as to optimize some objective function defined over the entire project's completion time. These decisions correspond to the selection of a probability function (from a set of alternatives, each with an associated cost) for the processing time of the given stochastic activity. For relatively simple network configurations, dynamic programming is shown to yield optimal decisions; for large complex networks, the efficacies of several heuristic scheduling rules are examined via simulation.

SS3B.5. Armanent Development and Test Center (ADTC) Flight Test Model, MAJOR DONALD L. OCKERMAN.

A mathematical model is proposed that views the flight test scheduling procedure for a particular mission as the problem of obtaining any permissible combination of the individual resources required. The probability of securing the needed, limited resources (aircraft, munitions, personnel, ranges, instrumentation, etc.) are evaluated in light of the mission's priority in relationship to competing programs desiring the same resources. Once scheduled, from reliability data, the model computes the probability of a productive mission. The model thereby enables ADTC to calculate a realistic time schedule for future test programs providing the priority and type and quantity of the required resources can be established.

SS3B.6. Simulation of a Multiphasic Screening Project, D. JAMES CROFT and RAY MILLER.

Multiphasic screening systems create the classical waiting line problem. These systems can be simulated with relative ease. This paper reviews the experience of the authors in simulating a proposed multiphasic screening project. The simulation allowed the authors to determine the proper configuration of facilities and equipment, plan manpower needs, and schedules orders for equipment needed in the future. The screening project's final configuration differed significantly from that proposed before the simulation. Several thousand dollars were saved. The paper presents several pitfalls that should be avoided in simulating multiphasic screening operations and outlines a general procedure for constructing the simulation.

SS3B.7. Lot Size Determination in Multi-Stage Assembly Systems, WALLACE B. CROWSTON and MICHAEL H. WAGNER.

In a multi-stage assembly system each stage requires inputs from a number of immediate predecessor stages and it supplies, in turn, one immediate successor stage. An efficient dynamic programming algorithm for lot size determination at all stages is derived for the infinite horizon case under the assumption of constant demand. For the finite horizon case with deterministic demand, an application of Benders' mixed integer programming algorithm is presented. For the special case of one predecessor for each stage, a dynamic programming algorithm is developed.

SS3B.8. Integrated Nonlinear Optimization/Simulation, GUY L. CURRY and RICHARD B. WADSWORTH.

The principal topic of this paper is a decomposition procedure for complex nonlinear optimization problems using simulation as the decomposition vehicle. To demonstrate the application of this procedure, a multi-product inventory example is given. Using this example as a basis, an attempt is made to generalize the characteristics of

this problem utilizing a general system theoretic approach. Tne technique is then applied to other problems having these general characteristics.

SS3B.9 Supply and Redistribution Rules for Multilocation Inventory Systems, CHADRASEKHAR DAS.

This paper deals with a multilocation stochastic inventory problem. It is assumed that stock is supplied periodically from a central source and there exists a provision for redistribution of stock over the locations. The supply and distribution decisions are assumed to be centralized. The redistribution is made on the basis of stock review at predetermined points in time between every two consecutive supply opportunities. Under certain regularity conditions, the optimality of a simple class of redistribution rules is established. The optimal supply rule is also characterized on the supposition that redistribution will be done in an optimal fashion. The relation of this model to known inventory models and its potential areas of application are mentioned.

SS3B.10. A Comparison of Quantitative Forecasting Procedures, JAY DEUTSCH and KIRTIKUMAR KATKAR.

Since sales forecasts form one of the basic inputs to business activity, it is essential that they are accurate and precise. To this end, quantitative methods, notably R.G. Brown's discounted least square algorithm and the more recent Box-Jenkins methodolgoy, have found considerable success. The foundations of each; the appropriate choice of a smoothing constant and the three stage iterative model building sequence are discussed. The accuracy and precision of each are compared from contours of mean square error and their associated confidence intervals that are developed for low order stationary and non-stationary processes. From these contours, the advantages of each approach are discussed and related to the characteristics of the occurring phenomenon.

SS3B.11. The Multiple Discretionary Priority Rule, MAXIMILIAN M. ETSCHMAIER.

In the multiple discretionary priority rule a customer can be preempted by a customer of higher priority if he has not received service of more than a constant, which depends on the classes of the two customers involved.

In the paper steady state results are developed from the results for the simple discretionary priority process by direct probability arguments. The policy is proved to be optimal for a linear cost function and a non-increasing expected remaining service-time function.

SS3B.12. The Parallel Theory for Matrices and Network Systems, S. GAUNT.

The Parallel Theory for Matrices and Network Systems follows the general concept for equivalent parallel resistors, where the respective column vectors of a matrix are expressed accordingly. Treatment of linear and implied non-linear situations are discussed by this work. The potential of the Parallel Theory appears to be in the wide scope of application, rectangular and square matrices, covering such problems as assignment, transportation, scheduling, network planning, switching networks, strategy, production planning, plant location, etc.

SS3B.13. A New Spares Optimization Approach Using Inventory Modelling Techniques, NORMAN GELLMAN and MORDECHAI LI-OR.

Presented here is a new solution to the problem of recommending optimal spares mixes for the military (several storage/repair levels).

The solution utilizes inventory techniques to describe spares demand rates. Customer constraints (costs and spares adequacy) and pipeline constraints (Delivery/repair time, component costs, etc), are utilized to yield the optimal spares nomenclatures for each storage locality, reorder cycle times, and storage quantities. This technique uses the expected number of failures to represent demand rates; (t,S) & (t,Z) inventory models (depending on lead time) to form the optimal solution.

SS3B.14. Experimental Design for the Simulation Study of a Disk Storage Device, AMRIT L. GOEL, P.S. NANDA, and S. MUKHOPADHYAY.

This paper deals with the problem of design of experiments in simulation studies. A review of the pertinent literature is presented and the results of an investigation into the response time characteristics of an IBM 2314 disk storage device are discussed. Full and fractional factorial designs are employed to study the effects of file structure techniques, file size etc. on the wait time, seek time and the total file system response time under some simplifying assumptions. Results of an optimization study are also included.

SS3B.15. GLM in Perspective, HARVEY J. GREENBERG and THEODORE C. ROBBINS.

A critical look at the current state of the art of Generalized Lagrange Multiplier Method is presented.

SS3B.16. The Dangers of Attractive Taxonomies, JOHN R. HALL, JR.

Researchers in the behavioral and planning sciences periodically seek to achieve major insights in compact form through the use of descriptive classification schemes. The line between a good and a bad classification scheme is a thin one, involving an objective examination of whether or not the prototypes of each class truly correspond with the characteristics of elements assigned to that class. This paper examines the role of taxonomies in research and some of the abuses to which they are prone. From these considerations, a number of conclusions are drawn regarding safeguards to be used in putting forward a taxonomy.

SS3B.17. Linear Programming in Electro Optical Systems Design, R. MICHAEL HORD.

The application of linear programming techniques to electro optical system design problems is discussed. Advantages and disadvantages of the approach and some avoidable pitfalls are described. These various features are illustrated by a simplified example. The example is then reworked to demonstrate the introduction of additional constraints and complexity. The example selected is the optimal choice of focal length and aperture for an aerial camera system to maximize station altitude under a set of constraints. The constraints may be diverse. Included in the example are constraints on weight, cost, resolution, light level, and the transverse moment of inertia.

SS3B.18. The Effect of Repairable Spares for a Multiple-Unit Standby Redundant System, DAVID L. JAQUETTE and SHUNJI OSAKI.

This paper extends the results of previous research which incorporated repair into multiple-unit standby redundant systems. Expressions for the first passage times to system failure and the state transition probabilities are obtained for a system with general failure and exponential repair times where the number of repair facilities is possibly less than the maximum number of failed units. Several numerical examples and the optimum design problems resulting are presented. Possible extensions and generalizations of the model are discussed.

SS3B.19. A Basic Approach to Evaluating the Effectiveness of VFR Control Towers, LAMBERT S. JOEL and WAYNE A. STEELE.

It is natural to assume that flow characteristics and collision probabilities will be different at airports distinguished by the presence or absence of VFR ("Visual Flight Rule", i.e. radarless) control towers. An attempt is made to establish statistically significant direct measurements of the differences, and to enumerate and quantify determinantal factors of flow disruption and accident rates related to tower presence. The study arose in connection with an FAA review of eligibility criteria for installation of VFR towers at airports.

SS3B.20. A Comparison of Computation Times for Various Starting Procedures, Basic Change Criteria, and Solution Algorithms for Distribution Problems, DARWIN KLINGMAN, FRED GLOVER, D. KARNEY and A. NAPIER.

Computational experiments were conducted on four solution techniques, four start algorithms, and four change of basic criteria for distribution problems.

The four solution algorithms compared were:

1) A general purpose simplex algorithm.
2) A special purpose primal simplex algorithm.
3) A special purpose dual simplex algorithm.
4) The out-of-kilter algorithm.

The analysis revealed that from among the procedures tested, the special primal simplex code (developed within the course of the investigation) is the most efficient algorithm for distribution problems, and the VAM "start" method is the most efficient of the primal start methods.

The analysis furthermore indicated that the best change-of-basis criterion among those examined is a modified "first negative evaluation" approach. Finally, the investigation revealed that one can make no valid conjecture about the computational efficiency of two implementations of the same algorithm unless the two computer codes are compared on the *same machine*, using the *same data* and the *same compiler*. Furthermore, if the computational comparison is performed on a multi-processing computer system, the codes must be executed during time intervals having approximately the same overall utilization of the computer system resources.

SS3B.21. A Multi-Plant Long-Range Capacity-Planning Model, P.T. LELE.

A long range discrete time multi-plant multiple demands centers problem, previously developed by the author and Dr. Cobian has been extended by the author to consider inventories explicitly and stochastically independent random demands. The model has also been extended to provide various constraints such as maximum inventory, maximum storage and budgetary limitations on available capital. The model is a dynamic programming master problem to make capacity decisions and linear programming subproblem to make production inventory allocation decisions. The cost functions are complex consisting of fixed cost and concave capacity addition costs which also depend upon preaddition capacity. The lead time necessary to add a plant or capacity is also considered. Various applications in manufacturing industry as well as non-manufacturing applications such as capacities to satisfy social needs are discussed.

SS3B.22. Transportation Problem with Variable Capacities, BENJAMIN LEV and LEON S. LASDON.

This paper deals with a class of multiproduct distribution problems where the products are differentiated only by the characteristic of size or packaging method. Each product can be produced in any of several plants and is distributed to many destinations such that total transportation costs is minimized. The optimum product mix for each plant can be determined by formulation of the problems as a set of transportation problems subject to the coupling constraint that each plant's total production cannot be greater than overall plant capacity. This algorithm is based on a sequence of solutions to transportation problems.

SS3B.23 Cost-Effectiveness Analysis Applied to the Authorization of Information Systems Projects, W. R. MAKI.

Systems development in industry is progressing from an established base of reporting and financial systems to operating, planning and control systems supporting the corporate decision-making process. This movement places additional pressures upon project justification decisions and the MIS portfolio supporting an organization or company. In particular, the importance and difficulty of adequately analyzing benefits and "intangibles" is highlighted with today's trend.

This paper will focus cost-effectiveness analysis upon alternate investment decisions in computer software and application systems. In addition, a framework and compendium of annotated approaches available to the systems analyst will be presented.

SS3B.24. The Production Rate of a Series of Work Stations with Variable Service Times, E. J. MUTH.

One of the important jobs of the industrial engineer is the design of production line systems. Significant features of a production line are (1) the number of work stations, (2) the processing time, or service time, at each work station, and (3), the amount of in-process storage provided between work stations. This paper reports the results of recent research pertaining to production lines with stochastic service times. A production line is treated as a collection of N work station, the ith station having a service time T_i, which is an arbitrarily distributed random variable. A novel mathematical description of the system is presented which is not restricted by the use of states, state transitions, and Markov properties. Exact solutions are obtained with $N = 3$ for: the production rate, the interdeparture time of items leaving the line and the interdemand time of items entering the line, the probability distributions of blocking time and idle time of the work stations. These solutions are functions of the statistical properties of the collection of T_i. For a number of work stations greater than 3 a sharp lower bound is obtained for the production rate. It is shown that the production rate for service times of small variance is substantially greater than that predicted by an exponential service time model.

SS3B.25. Stochastic Behavior of Two-Unit Standby Redundant Systems, TOSHIO NAKAGAWA and SHUNJI OSAKI.

This paper presents the stochastic behavior of two-unit standby redundant systems with the generalized assumptions that the failure and the repair times of each unit are arbitrary. The first passage time distributions, the transition probabilities, and the limiting probabilities are derived by using a unique modification of the regeneration point techniques of Markov renewal processes.

SS3B.26. The Equivalence of Integer Programs to Constrained Recursive Systems, PATANJALI S. NANDA.

It has been established that integer programs with integral, recursive constraint matrices have integral extreme points for integral, non-negative requirement vectors. In this paper, it is first shown that the assignment problem can be transformed to such a program, but with upper bounds on some variables. This equivalent program leads to additional results for solving the assignment problem. Algorithms are then delineated to transform matching, covering and travelling salesman problems to equivalent recursive programs of the aforementioned type, but with bounds on some variables. These results are extended to programs with only the elements 0, + 1 or − 1 in their constraint matrices.

SS3B 27. Designing Multi-Use, Multi-Facility Systems Using a Branch-And-Bound Algorithm, CHARLES E. PINKUS, DONALD GROSS and RICHARD M. SOLAND.

A model for designing multi-use, multi-facility systems is presented. Given the maximum number of facilities and their possible locations, the problem is to determine which facilities to include in the system and which activities should be carried on at each facility. A branch-and-bound algorithm is used to solve this problem, the subproblems being tractable integer linear programs. This model can be used in the design of such diverse systems as health care centers, schools, and multi-product multi-echelon inventory systems

SS3B.28. Assembly Line Balancing Including Station Change Costs, F.E PLONKA, FU-TONG HSE, and KAILASH C. KAPUR

An assembly line balancing problem which considers the cost of rebalancing the existing production line is formulated into problems of dynamic programming, zero-one integer programming, and combinatorial programming. Results from three different formulations are compared and discussed. Extension of this problem to a larger assembly line control problem are also discussed. The results indicate that the line balancing problem can be solved when there are penalties for changing operations to different work stations and that the line balancing problem will become one of gradual changes to existing lines. This problem is particularly relevant in U.S industries because major styling changes and plant shutdowns are expected to decrease.

SS3B.29. The Multiple Set Covering Problem A Side Stepping Algorithm, A. RAO.

This paper considers the multiple set covering problem which is a generalization of the set covering problem. An implicit enumeration type of algorithm is presented for its solution. The algorithm consists of a series of forward and side steps. The concept of a side step is introduced in the first section. The second section contains a statement of the algorithm. Subsequent sections contain an illustrative example, necessary theoretical development and, in conclusion, results of computational experiments.

SS3B.30. Semi-Markov Processes in Evaluating Shortage Costs, S. SUBBA RAO and MUHITTIN ORAL.

This paper investigates and derives a model to evaluate shortage cost parameters in inventory models utilizing the concept and results of semi-Markov processes. A customer with demand distribution $F(x) = \Pr[\xi \leqslant x]$ arrives according to inter-order time distributions $F_0(x)$ and $F_1(x)$ depending on whether the customer met no-stockout or stockout condition last time. α, the level of satisfaction factor is defined as the ratio of the number, $\mu_0(T)$, of times no-stockout condition is met to the total number, $\mu(T)$, of orders the customer places in time interval $(0, T)$. The total business volume $\eta(T)$ under no stockout conditions forms a stochastic process. The quantities $E[\eta(T)]$, $\mu(T)$ and $\mu_0(T)$ are computed to find the expected volume of business lost $E[\eta(T)]\,[1 - \alpha]$. The expected shortage cost per unit is then derived in terms of the lost volume of business and savings in holding and ordering costs.

SS3B.31 A Bernoulli Regression Model, H. C. RUTEMILLER and N. D. SINGPURWALLA.

We consider in this paper the general problem of point and interval estimation of parameters, θ_j, of a family of Bernoulli distributions, where θ_j, is a mathematical function of known parameters $X_{j1}, \ldots X_{jp}$. The total number of Bernoulli observations is assumed large, although a single observation may be available at each θ_j.

Point and interval estimates of θ_j are developed for a particular regression model, and a likelihood ratio test is suggested for the contribution of each parameter. The results are illustrated with a numerical example from the sport of horse racing.

SS3B.32. Disability Evaluation and Authorization—A Multi-Processing System, G. THEODORE SAFFRAN.

This paper describes an analytical evaluation of the disability claims workflow through an integral system of the Social Security Disability Insurance Program. The objective of the study was to analyze the sequential flow of this processing in order to establish an optimum network of processing stations. Primary efforts were directed in the following areas: workflow patterns; caseload volumes and types, and processing, queue, and elapsed time characteristics. Workflow was found to be principally a study in queueing and consisted of evaluating multiple channel, multiple service operations.

SS3B.33. Optimal Selection Among Project Alternatives, M. SEGAL and S. HALFIN.

A company anticipates a growing demand for its products or services and plans to engage in several projects. Each project can be executed in several alternative ways where the alternatives use various amounts of resources and involve different anticipated payoffs. It is required to select optimally among the alternatives subject to constraints on the resources. This problem is first solved for the one constrained resource case using a dual linear programming approach. For the case of two constrained resources a mixed method of Lagrange multiplier and dynamic programming is used.

SS3B.34. Operations Research for Risk Analysis Evaluation, JERRY SELMAN and VICTOR SELMAN.

Deputy Secretary of Defense Packard stipulated that a formal Risk Analysis be made on each major program throughout the life-cycle in order to reduce the risk of cost and schedule overruns and performance degradation. At present few operations research models have focused on the total TIME-COST-PERFORMANCE triad. The risk analysis formalization is so innovative that it emerges as a new systems technology for the economic "belt-tightening" compounded by the changing-value systems of the seventies. This paper illustrates the Risk Analysis concept, reviews progress to date, and suggests Risk Analysis applications for non-military systems.

SS3B.35. Feasibility of Regular Multidimensional Assignment Problem, MOHAMMED M. SHAMMA.

The simple assignment problem deals with two sets of elements to be assigned to each other optimally. A regular multidimensional assignment problem deals with more than two sets of elements (dimensions), with each set containing the same number of elements (index range), to be assigned to each other optimally, subject to a constraint set. The constraint set is specified by a constant (order). This constant indicates the number of indices kept fixed in each constraint. An assignment problem defined above becomes infeasible if a certain relation between the dimension, index range, and the order is violated.

SS3B.36. Tanker Berth Simulation, S.J. SPIERER.

A model which simulates port operations at an ocean terminal is presented.

The model is a planning tool used in determining the number of loading berth and storage facilities required at a port in order to prevent excessive tanker delays and inventory levels.

Output on berth utilization, refinery production slowdowns, and inventory levels is obtained. Case study results are included in order to illustrate the effect of various facility changes on these output statistics.

SS3B.37. Elimination Methods in the $m \times n$ Sequencing Problem, WLODZIMIERZ SZWARC.

Consider a $m \times n$ sequencing problem where the processing order of jobs through machines is given and the same for each job and the unknown order of the jobs through machines is the same for each machine. Given the processing times of each job on each machine, the problem is to find a processing order of jobs so as to minimize the total elapsed time. The paper presents a solution method which consists of eliminating sequences which are not optimal solutions, and finding the optimal solution in the reduced set. No other (of the known) method produces a smaller set.

SS3B.38. Optimal Pricing Rules for Stochastic Resource Allocation, G. THOMAS, G. W. WRIGHT and A. WHINSTON.

This paper presents some results of single period and multiperiod pricing models developed for the price setler under conditions of uncertain demand and/or uncertain supply functions. The problem of uncertain demand has traditionally been considered in the context of a price taker reducing the problem to inventory models. A

new approach is developed for optimizing decisions of the manager who can vary price. In this case the form of uncertainty changes from sterliastic demand to stochastic demand functions. Comparisons are made with pricing models under certainty and with pricing models under varying forms of uncertainty.

SS3B.39. Optimal Policies for Proportionately Stocked Products, ALLAN C. WHEELER.

Multiproduct stochastic periodic-review inventory models generally possess optimal policies of a complicated form. When inventory levels after ordering are constrained to be in a fixed proportion, however, more tractable solutions exist. Conditions are given for which simple multiproduct versions of (s,S) policies are optimal.

SS3B.40. Shop Sites and Customer Behaviour Pattern, Q. A M. M. YAHYA.

In auctioning different sites to be used for shops, petrol pumps etc., the municipal authorities wish to classify the sites in terms of the expected sales on the basis of the position of the sites. In an effort to derive an optimal system of such classification, it is pointed out that the density of population traffic around a site is often not conducive to big sales. For instance, a betel-cigarette retail shop near an airport or a busy round-about gets a few customers out of the heavy population traffic who are in busy mood, whereas such shop near a cinema, court-house or college campus gets a large fraction of the traffic as customers due to the leisurely atmosphere. Once the shops are established on payment of the computed values, the actual sales would, however, depend on several new factors like salesmanship, goodwill, inventory system, advertising etc. The paper discusses how far a disadvantage in site can be overcome by bettering these factors. This depends on the changes over time, the learning effect for concerned items amongst the heterogeneous population. The technique applicable here seems to be the behavioral equation of the Pavlovian type of learning experiments and Venn Diagrams (Cf. Yahya: Bull. Oper. Res. Soc. Amer. vol. *16*, p. B-260).

SS3B.41. Finding All Shortest Paths from a Fixed Node in Non-Negative-Distance Networks, JIN Y. YEN.

An algorithm for finding the lengths of the shortest paths from a fixed node to all other nodes in N-node non-negative-distance networks is presented. Theoretically the new algorithm requires only $\frac{1}{2}N^2$ additions and N^2 comparisons, which is only 60% of the effort required by Dijkstra's algorithm (elaborated by Dreyfus). When the new algorithm is applied N times to find the lengths of the shortest paths between all pairs of nodes, theoretically it requires only 75% of the effort required by Floyd's algorithm. An empirical study confirms the superiority of its efficiency. The applications of this type of shortest path algorithm in a variety of related fields and a FORTRAN IV computer program for Dijkstra's, Floyd's, and the new algorithms are also presented.

SS3B.42. Sequencing N Jobs, with Stochastic Processing Times, on Two Machines, A.A. CUNNINGHAM and S.K. DUTTA.

This paper treats the problem of sequencing N jobs on two machines in a "flow shop". (That is, each job in the shop is required to flow through the same sequence of machines.) The processing time of a given job on a given machine is assumed to be distributed exponentially, with a known mean. This paper gives a proof of a previously conjectured rule for ordering the jobs so as to minimize the expected job completion time. Moreover, a formula is derived through Markov Chain analysis, which evaluates the expected job completion time for any given sequence of the jobs.

SS3B.43. Network Model for Transportation System, EUGENE E. PAYNE.

A significant part of the Emergency Care System in a metropolitan com-

munity is the transportation system. This paper describes a network model for scheduling the units in the emergency transportation system. The model provides for the consideration of varying traffic patterns and for both air and surface emergency transport units.

In addition to computational results and considerations, a brief description of the theoretical basis (shortest chains in a directed, multiterminal network) is presented.

SS3B.44. The Design of the National Right-to-Read Effort, ROGER L. SISSON.

The National Right-To-Read Effort consists of many coordinated activities in the private and public sectors, designed to eliminate functional illiteracy by 1980. The strategy and plan were designed over a period of a year by several task forces. These groups consciously used two "soft" (non-formalized) models: the convergence model (Louis M. Carrese and Carl G. Baker, "The Convergence Technique. .", *Management Science,* Vol. 13, No. 8, April, 1967) for R & D program management and a model of the processes of innovation in the public sector (proposed by the author).

The presentation covers the history of the project, an evaluation of soft models and a discussion of the conditions under which they can be used.

SS3B.45. Multicommodity Networks with Resource Constraints: The Generalized Commodity Flow Problem, RICHARD D. WOLLMER.

Previous work on multicommodity flows has treated networks in which individual arcs have flow capacities. This paper generalizes that notion to include capacities on linear combinations of flow on several arcs, thereby greatly increasing the scope of problems that can be treated. Some of the multicommodity situations treated here which have not been handled previously are the allocation of directional flow in undirected arcs; node capacities; multimode networks with limited vehicle supplies; and the efficient use of scarce resources. In addition a new solution technique is given which should prove more efficient than those given previously for the classical multicommodity flow problem.

SS4A.1. Problems of Identification of Social Cost, HOSSAIN AHMADI and JOHN VAFAI.

Social Costs of corporate activities comprise a wide spectrum of cost elements, ranging from vaguely conceived economic phenomena, e.g. social cost of operating a petroleum reservoir under non-maximum efficiency rate, to widely publicized social cost elements, e.g. social cost of air pollution by the automobile industry. In the absence of a rather precise understanding of social cost, definition and delimitation of corporate social responsibility is difficult, if not impossible. Any "accurate" corporate decision must necessarily include the classical cost theories as well as social costs, e.g. technological, environmental and human costs. Thus a multidisciplinary approach is presented in this paper for the understanding and identification of social costs to be incorporated in management decision processes.

SS4A.2. Generalized Expressions for the Minimum Time Interval Between Consecutive Arrivals at an Idealized Railway Station, DIETRICH R. BERGMANN.

This paper presents recently derived solutions for the minimum time interval between successive arrivals at a station in a railway system. Seven independent variables are identified and the problem is formulated mathematically. A sequence of lemmas and theorems leads to the derivation of four expressions for the minimum time interval. The

solutions are then compared to less general previous results and applied in the development of conclusions regarding the operational control and design of vehicles.

SS4A.4. Systems Engineering Develops a Highly Mechanized Bulk Mail Handling Facility, ROBERT J. CARDINAL.

A new integrated material handling concept has been developed, designed, and is now under construction to handle and sort over 500,000 parcels per day to approximately 1,400 destinations. A systems approach was taken, i.e., an optimum facility design was developed by evaluating all the significant design decisions in terms of their effect on the total facility investment and operating costs. Through the use of operations research techniques, industrial engineering and practical materials handling, an entirely new equipment configuration was developed which significantly increased labor productivity, thus making it economically feasible to mechanize traditionally manual processing operations.

SS4A.4. Mathematical Approaches to Timber Management, RICHARD J. TAYLOR and BARNEY L. CAPEHART.

Many of the problems of timber management lend themselves to mathematical modeling and solution. This paper describes procedures currently used by the U.S. Forest Service in Florida's Ocala National Forest to plan timber harvesting and estimate the success of timber regeneration operations. Some possible alternative planning methods and performance measures are devised. Topics discussed include sampling methods used to estimate the success of seeding operations, and performance measures to aid in the selection of timber stands to be harvested. Dynamic programming and integer programming techniques are considered for determining optimal harvesting policies. Digital simulation results will also be presented.

SS4A.5. An Optimum Spraying Policy for the Control of Insect Polulation, SAMPRIT CHATTERJEE.

Increasing attention has been drawn to the haphazard and indiscriminate spraying of crops by insecticides. The present paper attempts to develop an optimal theory of spraying for the control of an insect population. A spraying program will involve several cost components. A stochastic model is constructed for the population, embodying the regular features of a biological population. A control program which minimizes the total cost is worked out. The total cost cab be represented as a function of the number of insects, the strength of the dosage, and the frequency of spraying. Finite and infinite time horizons are considered.

SS4A.6. State Inspection of Automobiles to Monitor the Performance of Exhaust Gas Emission Control Systems, FRANK A. COLLINS and GERALD J. THUESEN.

This paper investigates the design of a system for inspecting automotive exhaust gas emission control systems. The inspection will:

1. Determine the exhaust gas emissions,
2. Determine whether the exhaust gas emissions control system is performing properly,
3. Prescribe a remedy if emissions exceed standards.

The objective of the study is to determine the cost-effectiveness of such a system. In determining the total cost of various system configurations, the costs of test equipment, inspection facilities, land, personnel, maintenance and operation are considered.

The effectiveness of the system is evaluated by computing the anticipated emission reductions that would be achieved through better control of automotive emission control systems. The three major pollutants from automobiles—carbon monoxide, hydrocarbons and nitrogen oxides—are included in the measure of effectiveness.

A variety of system configurations are studied to attempt to satisfy user convenience (waiting time for inspection test) criteria. This study is based on providing such an inspection system for the five county Metro-Atlanta area, and available data are used.

SS4A.7. A Continental Energy Policy and Planning Model, J. G. DEBANNÉ

The problem of investments in oil, gas, coal, nuclear and hydro power and distribution capacity as well as the problem of energy commodity allocation and substitution in the market place are treated within a multi-stage, multi-commodity network flow model. Features of the model are:

A mapping algorithm to map in network notation the real world components and attributes of the system as energy commodity sources, demand centers, prices, tariffs, quotas, substitution effects in the market place, pollution control costs and technology effects.

A stochastic hydrocarbons exploration model to relate investments and exploration technology to the discovery of oil and gas.

A pricing mechanism relating the various forms of energy to that of oil, via the dual costs.

SS4A.8. Minimizing Regional Pollution Control Costs, ROLF A. DEININGER and SHIAW Y. SU.

With the demand of the public for a cleaner environment the costs of pollution control will increase vastly. No great breakthrough in waste water treatment technology can be expected, at least not costwise, and thus the only hope of lowering these costs is to encourage industries and municipalities to join together in common treatment facilities to take advantage of economies of scale in waste water treatment and transport. It is the purpose of this paper to show how the methods of systems analysis may be used to plan for more efficient new pollution control facilities, or how to upgrade existing systems. The particular problem investigated is the following: Given a region with a number of industries and/or municipalities, where should one build treatment plants and what interconnecting trunk sewers are necessary to minimize the total regional cost of waste water treatment and transport? The mathematical formulation of the problem is presented and the special algorithm and computer program developed to solve this nonlinear problem is shown.

SS4A.9. Economic Model of Transportation in a Small Federal Recreational Area, LUCIEN DUCKSTEIN, WALTER D. THOMPSON, GARY B. WILLIAMSON.

An economic model was developed to evaluate transportation systems in a small National Forest recreational facility serving an urban area. A proposal to increase capacity by banning cars and providing a park bus service was modeled and compared to the condition of allowing cars to remain but curtailing the level of service. Preliminary calculations indicate that based on Collective Utility the banning of cars is a better choice than limiting service.

SS4A.10. Collective Utility: A Systems Approach to the Use of Natural Resources, EDWIN DUPNICK.

The collective utility approach considers marginal (evolutionary) changes of economy in contrast to the structural changes (e.g., "build, or not build") investigated by the techniques of cost-benefit and cost-effectiveness. Quite often the latter two techniques frequently lump intangibles into a single sector, or exclude them altogether by labeling them "externalities." It is the thesis of this paper, however, that an effective control of externalities (e.g., pollution) will result in the effective use of natural resources. A systems approach is needed to evaluate the impact that externalities have on an economic area-collective utility is suggested. Accordingly, this paper develops a utility calculus based on simple by explicitly defined hypotheses, in order to analyze the net-

work flow of goods, services, and natural resources. Using this calculus, a policy is derived in conjunction with calculus of variations to utilize natural resources efficiently (with consideration of externalities) in a case study, and ensure a continual growth in public benefits.

SS4A.11. Cost of Optimization for the Design of Trickling Filtration Process in Water Pollution Control, G. ALLEN ELLIFF, CHIA SHUN SHIH, and W. L. MEIER, JR.

A practical cost model for the trickling filtration process on waste-water treatment has been developed. The model is optimized using a pattern search with summation of gradients to determine the minimum annual treatment cost. The objective function includes costs for the tank structure, media, underdrains, distributor, recirculation pumps, electricity, and the cost of excavation. Other costs included are land cost, final clarifier cost, operating and maintenance cost, and the cost of piping. Sensitivity analyses in terms of varying inflow qualities and quantities has been conducted. The potential gain and future opportunity of the cost optimization for water pollution control process are discussed.

SS4A.12. Simulation of a Parcel Sorting Factory for the U.S. Post Office, RONALD A. HABERMAN.

A special class of mail, called "Parcels," is handled differently than the more traditional type of letter and magazine. The Post Office is looking for a design of Parcel Sorting Factories to handle this type of mail. A mathematical model examines different physical layouts for optimizing throughput of these futuristic Post Office facilities. Although restricted in some ways by certain design criteria, we were able to examine many alternate designs by way of computer outputs.

SS4A.13. The Evaluation of Product Bans in the Public Interest, JOHN R HALL, JR.

A recurring problem for legislative bodies is the consideration of proposals to ban a class of products. This paper presents a methodology for assessing bans which takes into account economic factors, legal issues, and alternative forms of correction and compensation. Cost-benefit analysis is embedded in a framework which examines the special features and effects of the ban option, and establishes procedural guidelines for assessment of bans in light of these properties. The non-returnable beverage container issue, which prompted this study, is examined, as are a number of other currently recommended bans.

SS4A.14. Methods of Problem Solution Applied to the Development of a National Bulk Mail System, RONALD W. HARDY and TERRELL J. HARRIS.

This paper describes a series of studies related to the design of a national bulk mail handling system. These studies cover the design of processing systems within each of twenty-one proposed facilities and transportation within the service areas for each of the facilities.

Emphasis is on the approach taken and the application of relatively simple techniques to extremely complicated problems. Sensitivity analyses indicated that the lack of guaranteed optimality in the use of many of these techniques is not significant.

The problems studied range from analyses of individual processes to consideration of the entire national system.

SS4A.15. Framework Model for a Nuclear-Agro-Industrial Complex, SAYEED HASAN, RICHARD B. WADSWORTH, WILBUR L MEIER, JR.

Nuplex is a coined word intended to describe a very large complex consisting of a nuclear power reactor, electric production, agricultural production, water desalination, chemical processing and production, and associated activities. This concept is relatively new and is based on low-cost, abundant electricity and water. The design and operation of these interrelated enterprises offers many potential opportunities and as-

sociated problems. A method is proposed for examining alternative Nuplex configurations. A general framework model is described which will provide a basis for detailed analytical and computer simulation models of Nuplex components and of a total Nuplex system.

SS4A.16. Interdisciplinary Solution of U.S. Post Office Safety Problem, LESTER KOLOM.

The United States Postal Service offers a fertile field for OR and systems scientific strategies due to former inconsistent goals of "Production expediencies concomitant with safety demands upon the work force". Recent investments in mechanized equipment, innovative IE techniques and professional safety resources have improved productivity while keeping accident losses at an acceptable management risk level.

The proposed paper is the complete account of a successful group involvement in a unique "Hawthorne Effect" experiment that resulted in a statistically significant safety success at an installation with approximately 200 employees.

SS4A.17. Development and Application of Procedures for Testing Cost Functional Forms: The Development of an Optimal Water Quality Treatment Program, JAMES R. MARSDEN, DAVID PINGRY, ANDREW WHINSTON.

This paper presents some initial results of research currently being conducted by the authors on the development of an optimal water treatment program. Several cost functional forms are considered first using recently developed techniques which are presented in detail in the paper. A cost minimization solution is approached using a recently developed algorithm.

SS4A.18. Detection of Power-Plant Thermal Pollution in Rivers by Communication Systems Techniques, J. C. MAXWELL, LELAND L. LONG, B. E. GILLETT.

Statistical communication theory is utilized to establish a method of measuring power-plant thermal pollution of river waters. A spectral decomposition of temperature fluctuations which is based upon continuous real-time temperature measurements is presented. An analogy is made between the thermal system and an electronic communication system. In this analogy, the transmitter (power plant) emits signal energy (heated discharge) into a noisy environment (river with its characteristic fluctuations). The receiver (temperature measuring device) picks up a combination of signal energy plus noise. This signal plus-noise is then processed and filtered to establish sensitivity requirements on the receiver.

SS4A.19. Comparison of Water Pricing Structures from a Collective Utility Viewpoint, BILL METLER and LUCIEN DUCKSTEIN.

The influence of water pricing structure on a region is approached from a collective utility viewpoint, the case of water distribution by the City of Tucson is chosen to illustrate this approach. The present pricing policy is a regressive block rate; two alternative structures considered are a progressive block rate around the year or one such rate during the summer only. A mathematical expression for the collective utility based on simple but clearly stated assumptions is proposed. The value of this collective utility determines which price structure should be adopted as a function of the parameters of the model. This model enables one to ascribe a value to conservation when a permanent progressive rate structure is used to decrease the total consumption. Savings on capital expenditures may also be realized whether such a structure is used all year or during the summer only by covering peak consumption. It is suggested that such an analysis of price structure be made in every district where water is a scarce resource.

SS4A.20. Systems Analysis of Urban Water and Liquid Waste Management: A Case Study, JOHN J. McCORD.

Two critical and strongly interconnected problems facing all urban communities are (1) assurance of an adequate supply of potable water, and (2) adequate

processing and disposition of sewage. Optimal long-range urban planning requires that both of these problems be analyzed together in a systems context, with all relevant issues—engineering, hydrologic, biological, ecological, economic and legal—being considered. Such an interdisciplinary case study was carried out for a medium-sized California urban area, with the goal of preparing a comprehensive water/sewage master plan. Procedures, problems and results of this study will be presented.

SS4A.21. The Application of Quantitative Expert Judgment in Cost-Effectiveness Analyses of Environmental Monitoring Systems, GAYLORD M. NORTHROP, EARL L DAVIS, EDWARD R. SWEETON, WILLIAM F. MERLIN.

The National Oceanic and Atmospheric Administration's National Data Buoy Project Office (NDBPO) has contracted with The Center for the Environment and Man, Inc., to develop a computerized cost effectiveness methodology for detailed tradeoff and sensitivity analyses of data buoys operating as separate environmental monitoring systems or as components of total National Marine Data Collection Systems, comprising data buoys, satellites, ships, aircraft, and other types of data collection platforms.

A salient feature of this cost effectiveness methodology is the incorporation of extensive amounts of quantified expert judgment in the form of continuous and discontinuous nonlinear Relative Worth Curves relating data worth to the meeting of data collection requirement characteristics. Other quantified expert judgment is incorporated as Relative Importance Weights associated with environmental parameters to be measured; layers in the vertical column where observations are to take place; sites at which observations are to be made; and regions within which observation sites are required.

CEM has collected quantified expert judgment from 10 individuals in the environmental data-using field, including military and non-military government data users and private commercial data users.

To demonstrate the viability of employing quantified expert judgment in cost effectiveness studies and to demonstrate the operability of the computerized cost effectiveness methodology, CEM has evaluated more than 200 alternative environmental monitoring system concepts. This paper presents a summary of the tradeoff and sensitivity analyses that have been performed.

SS4A.22. Impact Statements on Nuclear Power: 1970s and 2070s, JERRY S. OLSON.

The 1969 U.S. Environmental Quality Law requires narrative statements and some calculations of diverse "impacts" of new facilities on the ecology of man, landscapes and waters. Between "perfect" operation and the incredible contingencies of huge accidents (which are addressed routinely in Safety Analysis Reports) lies a middle-range of plausible, occasional releases of radioactive isotopes which deserve an actuarial outlook, plus modeling of consequences. Examples contrast (a) immediate decision-making while both the risks of loss and experience for judging costs remain low, *vs.* (b) long-range possibilities when cumulative impacts, and experience for judging their consequences and trade-offs, are much greater than we have in the early 1970's

SS4A 23. Modelling Experience on the University of Michigan Sea Grant Project, R. L. PATTERSON.

Broadly speaking, the objectives of the Sea Grant Project at Michigan are 1) to develop a method for studying the physical, chemical, and biological behavior of Lake Michigan, 2) to develop specific mathematical models which explain and predict certain key attributes of this aquatic resource; 3) to develop an effective means of communicating the results to persons outside the University community.

The method under development involves a team approach which couples researchers from Engineering, Natural Sciences, Public Health, Law, Social Research Institute, Business and Biology. Mathematical model building involves description of physical, chemical, and biological processes, land use suitability analysis, impacts of land use on water quality, and quantitative description of political institutional interactions.

SS4A.24. SERF: A System for Equipment Requirements Forecasting, R. JOHN PREVOST.

A system has been developed for the United States Postal Service for forecasting non-fixed, non-mechanized portable operating equipment requirements. The method incorporated involves three steps: 1) Stepwise multiple regression analysis is used to relate actual equipment inventories to current values of workload parameters, 2) Expected future values of the workload parameters are determined by use of weighted moving averages (exponential smoothing); 3) Projected parameter values are inserted into previously determined regression equations to yield expected equipment requirements. The system developed, SERF, is composed of five modular, independent computer programs which rely on off-the-shelf parameter data as input. One to five year requirement forecasts have been produced.

SS4A.25. Space-Time Sampling of Ecological Systems, HASSAN QUASHU, LUCIEN DUCKSTEIN, CHESTER KISIEL.

The design of sampling schemes of ecological systems depends upon decisions to be made about those systems. Sampling for eutrophication in Lake Mead is considered, where the decision is to stop loading the lake if eutrophication is taking place, to continue loading otherwise. Economic and social costs of errors, waiting, sampling and processing data are taken into account. Physical constraints stem from the complexity of the process in space, time and from sampling technology. The methodology proposed here develops alternative cost-effective space-time sampling schemes for an aquatic system and can be transferred to most ecosystems.

SS4A.26. Cause and Effect Diagrams as an Aid to Systems Formulation in Solid Waste Management, ADARSH SAIGAL and DILEEP SULE.

The cause and effect diagrams are simple extensions of the widely used black box models. As the problem size and complexity grows the use of these diagrams becomes indispensable. The benefits of these have been substantially noticeable for intricate problems like 'Solid Waste Disposal.' Before mathematically formulating a system, this method of visual representation helps in identifying key problems. This is so because once the effects are listed, we can work backwards and find out the assignable causes. It was found very helpful to work with subsystems, and then to synthesize these to get a cause and effect diagram for the whole system. Many important parameters were thus revealed.

SS4A 27 The Potential of Dynamic Programming in Assessing the Crises of Water Pollution, CHIA SHUN SHIH and JOSEPH K. GARNER.

This paper shall discuss the opportunity and potential gain of dynamic programming applied to water pollution control in terms of microscale and macroscale analyses. Microscale problems are those concerned with the managerial objectives of basic decision-making element in water pollution control, such as the optimization of unit process and wastewater treatment schemes. Macroscale problems are those concerning larger scale systems with complex managerial decision-making elements such as regional water quality control and river basin management. The models embedding dynamic programming will be presented and illustrated with numerical examples using practical cost relationships.

SS4A.28. Environmental System Synthesis, MAURICE H. SIMPSON.

Existing state-of-the-art in attacking environmental problems has resulted in sub-optimizing about elemental limits without being able to define specific environmental control requirements. Furthermore, existing environmental systems analyses are open looped at the environment-information point. In this paper the author develops methodology that will close these loops. He plants a "system" into an "organism". The concept is that a system is an artifact and the organism is a body corpus, e.g., natural environment, a group, community, or society. This synthesis permits vibrations to the system

output in terms of needs of the organism, and inputs environmental effects to the control mechanism. Applications of servomechanism and system assessment techniques are demonstrated.

SS4A.29. Extreme Values from a Lognormal Law with Applications to Air Pollution Problems, N. D. SINGPURWALLA.

In this paper an attempt is made to show how certain empirical relationships observed in an analysis of air pollution data can be explained using extreme-value theory. In order to accomplish this, it was necessary to establish that the limiting distribution of the maximum term of a random series from a lognormal law belongs to the domain of attraction of the double exponential limit law. By studying the behavior of the median of this limit law with respect to the "averaging time"; a quantity used in air pollution monitoring, the empirical relationships can be explained. Potential applications of the extreme value theory to problems of air quality are pointed out.

SS4A.30 Techniques for Selecting Particulate Air Pollutant Control Equipment, CHARLES WILLIAM STONE.

The need for particulate control equipment has been well documented, but systematic methods of selecting the equipment are far from being established. Utilizing adaptive identification procedures, an idealized mathematical model of the desired particulate control system is formulated. By applying appropriate criterion functions, Geometric Programming and parameter-estimation techniques, the parameters of a feasible particulate control system are synthesized in such a way that the difference between the idealized model response and the actual system response is minimized. This selection and automated parameter adjustment procedure yields a particulate air pollutant control system which is optimal with respect to the physical and economic constraints imposed upon the system.

SS4A.31. Optimal Operating Policies for Multiple-Purpose, Multi-Reservoir Systems, SHIAW Y. SU and ROLF A. DEININGER.

The systems considered in this paper consist of m reservoirs which are connected in series and arbitrarily located on the same stream; the release from one reservoir constitutes a part of the input to the next downstream reservoir. The monthly water supply to each reservoir is treated as a stochastic random variable. The systems can be modeled as large-scale, periodic Markov chain decision problems. White's method of successive approximations for a single-chained completely ergodic Markov process is very efficient in handling large-scale problems. It was extended to the case where the Markov chain is periodic. The problem of optimal lake level regulation of the Great Lakes was formulated as a Markov process. Computational experiences with the model will be discussed.

SS4A.32. A Linear Programming Model for the Selection of Refuse Collection Schedules, M. TANAKA and J. E. QUON.

This paper presents the development of a linear programming model for establishing refuse collection schedules. The selection of a collection schedule is based on economic and efficiency criteria. Operating costs and the cost associated with poor service are considered.

The influences of several parameters such as overtime policy, penalty cost factors, and truck assignments, on the optimum schedule were investigated with the aid of the model. A comparison of the optimum schedule with those used in practice is presented.

SS4A.33 The Systems Model in Water Resources Planning, BILLY M. THORNTON and W. L. MEIER, JR.

Typical objectives of water resources planning are briefly reviewed. Emphasis

is placed on sufficiently detailing objectives so that they are of value to the system designer. A verbal statement of an objective so specified is termed a goal-statement. Mathematical systems theory is used to model the goal-statement and the resulting system. An example problem is formulated in accordance with these models and the resultant formulations are evaluated through simulation. The intent of the paper is to illustrate currently available concepts of use in the representation and evaluation of objectives and systems in water resources planning.

SS4A.34. Management Science and Gaming. An Aid to Decision-Making in Ecology, P. N. WAHI and T. I. PETERSON.

Interrelationship of the numerous factors in ecology can be explored in a gaming environment. Management Science aids can also be introduced to guide the decision-making. An experimental prototype game has been devised which implements these objectives. It is interactive, terminal-oriented and programmed in APL. The scenario for the game treats the environmental area of solid waste management. It is directed to players with minimal knowledge of management science. Techniques include shortest route, transportation and maximal flow problems. The system supporting the game can generally be used to author other game scenarios. Features stress interactive, natural language communication and prompting.

SS4A.35. Centralization of Waste Treatment Facilities, MARTIN P. WANIELISTA and CHRISTIAN S. BAUER.

Relatively few sewer, water, and wastewater systems in the world are planned within water resources limitations and population expansions. Most urban systems are non-optimal aggregates of poor planning. In the State of Florida, more than 2 billion dollars should be invested in the construction of these systems within the next few years. Optimization in the planning of Florida systems could result in the savings of millions of dollars. Mathematical models for the planning of these systems will be presented. A case study illustrating these models will be presented to demonstrate the economic advantages of planning waste treatment facilities within water resources limitations.

SS4A.36. Modern Theory of Filtration Process on Water Pollution Control and its Optimization by Combined Mathematical Programming Techniques, DUANE J. WRAY and CHIA SHUN SHIH.

To cope with the ever-increasing crisis of water quality deterioration, the technological refinements for water quality improvement are urgently needed. Filtration process has been the most essential unit for both water purification and advanced wastewater treatment. Within the next decade, the expenditures of filter constructions for water purification alone are estimated well above 600 million. A cost model for filtration process integrating the modern filtration theory and practical cost information has been formulated. The optimization for filter operational parameters is attained and will be demonstrated by the combined use of both geometric and linear programming.

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